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GEOLOGICAL SURVEY.

J. E. CARNE, F.G.S., Government Geologist.

MINERAL RESOURCES.

No. 24.

THE MOLYBDENUM INDUSTRY IN NEW SOUTH WALES.

BY

E. C. ANDREWS,

Geological Surveyor.

SYDNEY: WILLIAM APPLEGATE GULLICK, GOVERNMENT PRINTER.

1916.

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Frontispiece.

Sachs' Mine, Kingsgate, 22 miles east of Glen Innes.
Three Specimens—5 cwt., 6 cwt., and 80 lb. respectively—torn from one mass of Molybdenum.

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LETTER OF TRANSMITTAL.

Geological Survey,
Department of Mines,
Sydney, 21st November, 1916.

Sir,

I have the honor to submit for publication Report, No. 24, of the Mineral Resources Series on The Molybdenum Industry in New South Wales, by Mr. E. C. Andrews, B.A., F.G.S., Geological Surveyor.

Molybdenum is much needed in the production of high speed steels, of steels of especial strength, of stabilizers for high explosives, and in other materials for munition purposes.

The molybdenite deposits of this State are highly important, being second in the list of the world's producers of this mineral, Queensland being first.

Although New South Wales exported only 32 tons of high grade molybdenite concentrates during 1915, it is highly probable that the output could be largely augmented, as there are large low-grade deposits of promise in the State, which will probably be developed in the near future.

Mr. Andrews' work has been prepared with great care and thoroughness; its appearance at the present time—when the demand is great, and the value high—should stimulate interest, and encourage development.

I have the honor to be,
Sir,
Your obedient servant,
JOSEPH E. CARNE,
Government Geologist.

The Under Secretary for Mines.

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The Molybdenum Industry in New South Wales.

I.—INTRODUCTION AND SUMMARY.

The molybdenite industry, especially in regard to the treatment of the ore, is only in the "pioneer" stage, and it is felt that the present report may be useful as a signpost to indicate the phase which this important industry has reached. It is recognised also that the report may be regarded as antiquated within a few years, owing to the rapid improvements being effected in the treatment of the ore. The fact itself that customs works charge from £1 10s. a ton upwards for the treatment of concentrates, even with oil flotation, shows that much remains to be ascertained in the way of simplifying the process. Nevertheless, it seems advisable to co-ordinate our present knowledge, so as to place the main facts connected with the industry before the mining community, so that the various deposits of the State may be viewed in the one perspective. The better to show the position or niche occupied by New South Wales in the Molybdenite Industry of the world, a special chapter has been inserted concerning the main occurrences of molybdenite throughout the world. Further reference may be found in the chapter on the outlook for the industry.

General.—It is now many years since the pioneer work of Clarke, Daintree, and Wilkinson showed the intimate relation of the valuable mineral deposits of the plateau and coastal provinces of Eastern Australia to the great masses of granitoid rocks forming the buttresses of the plateaus therein.

Some of these occurrences are very large, some small, some are dark in colour and contain much hornblende and black mica, some are coarse in texture, granular or porphyritic in texture, many again are fine in texture and of granular habit and are composed essentially of small grains and crystals of quartz and felspar, well interlocked.

It is coming to be known generally that these types occur together in many large areas, the dark types being the oldest, while those of fine texture and a high proportion of silica content, seen in nature as an abundance of sand grains in the rock, are the youngest or intrusive members of these granitoid assemblages.

In general the darker, that is the more basic, types, are associated with gold and copper deposits; the coarse, sandy, and granular types with molybdenite and bismuth (in New South Wales); while the very sandy types, which form striking topographic features in the landscape by reason of their resistance to the agencies of denudation, are characteristically associated with tin and wolfram, especially with tin in New South Wales. The latter types where carrying *tin deposits* of importance, contain molybdenite in flakes well scattered, but not of commercial importance. In southern New South Wales these granitoids may be closing-Devonian in age, while they appear to be of late or closing-Permo-Carboniferous age in New England and in North Queensland.

Around the margins of the coarse sandy types, especially in New South Wales, molybdenite and bismuth deposits occur, and with them wolfram may occur rarely. These deposits occur in the coarse granite, generally as pipes of quartz or granitic material. An exception to this rule is to be found at Yetholme, in the Bathurst district, where the molybdenite occurs as a contact deposit associated with limestone, claystone, and quartz porphyry near sandy granite.

From time to time deposits of molybdenite, hitherto unknown or unprospected, are reported from the margins of certain coarse and sandy types of granite, and it is hoped that the publication of this report may be useful in directing further attention to these granite masses of the Bolivia, Booroolong, Deepwater, Monaro, Moonbi, Rocky River, Tenterfield, and other areas, prospected as yet only in part.

In the report also is implied the advisability of mapping and classifying the composite granitoid masses in New South Wales.

II.—ACKNOWLEDGMENTS.

The list of the names of all those who have supplied information for the preparation of the present report would be a very long one, and only those who have supplied information of major importance are here mentioned.

Mr. W. H. Yates, of Bondi, has supplied the luminous notes from which the history of the Kingsgate field has been prepared, and every facility was afforded by Mr. Yates for the inspection of the very numerous and important deposits known as Yates' Pipes.

Mr. Wm. Marshall, and his brother, Mr. H. Marshall, have a first-class knowledge of the local conditions of mining at Kingsgate, and to their kindness in supplying notes on mining at Kingsgate the report on Kingsgate owes very much of any value which it may have.

To Miss P. Speckhardt the writer is indebted for assisting in making the survey of the Kingsgate properties, outside those belonging to Mr. Yates, as complete as possible in the limited time at his disposal.

To Mr. D. Munro and Mr. Hagen are due the notes on the Old 45 or Sachs' Mine.

To Mr. T. Schafer, of Whipstick, cordial thanks are due for showing the writer many spots of geological interest at the Whipstick Mines. Cordial thanks are due also to Mr. Schafer, Mr. J. Scantlebury, and Mr. H. Robertson, for information concerning the Whipstick Mines, Ltd.

To Messrs. J. H. Fawcett, F. Cape, W. L. Garrard, H. Marshall, and Mr. Bethell, cordial thanks are due for general information concerning the interesting Yetholme deposits.

To Messrs. E. W. Finch and A. Pedley are due the notes on Bow Creek Mine, and for general information on molybdenite mining.

To Mr. A. Collins, of Deepwater, cordial thanks are due for conducting the writer to numerous molybdenite deposits at Deepwater and Bolivia ; to Mr. E. A. Baker also for information regarding the Allies and other mines.

Cordial thanks also are due to Messrs. Frank Roberts and F. Heiss for information concerning the Rocky River deposits; to Mr. Percy Reid for conveyance to the Wunglebung deposits; to Messrs. Percy Reid and Hughie Weir for information concerning the remarkable Boundary Creek deposits; to Mr. Betts for conveyance to the Haystack Mountain, and information concerning same; to Mr. A. E. Cooper in connection with certain Bolivia deposits; to Messrs. Cadogan, T. Betts, and Russ in connection with the Moonbi deposits; to Mr. W. Balmain for conveyance to the Tantawanglo deposits, and to Messrs. Bush, Knox, and Fulton in connection with these deposits; to Messrs. Edwards, Jackson, and Wachman in connection with the Black Range deposits, and to Mr. H. H. B. Deane for conveyance to the Wymah deposits.

A joint inspection of Yetholme was made by Mr. J. E. Carne, Government Geologist, and the Writer, in June, 1915, while notes on the Nambucca or Warrell Creek field have been supplied by Mr. Carne.

Notes on various districts and deposits have been supplied by colleagues, especially on the Carrai, Manildra, and Serpentine or Guy Fawkes areas, by Mr. M. Morrison, on the Warrell Creek deposits by Mr. J. R. Godrey, on the

Holbrook and Wymah deposits by Mr. H. Hooke, on the Bega and Delegate area by Mr. D. Milne, on the Monaro area by Mr. Leo. Jones, on the large New England area by Mr. George Smith, and on the Western District by Mr. J. Carthew.

Lists of occurrences were supplied by the various Wardens, and many places were shown to the writer by Mr. Warden Perry, in whose district the great bulk of the deposits occurs.

Plates II, III, and IV have been reproduced through the courtesy of Mr. C. Y. Caird, of Sydney, by whom the original photographs were taken in North Queensland. Plates V and VI have been reproduced from Mr. L. C. Ball's negatives by the courtesy of the Queensland Department of Mines and the Editor of the *Queensland Government Mining Journal.*

Plates I, XII, XVI, and XVIII have been reproduced from photographs kindly supplied by Miss Speckhardt. Plates XXV, XXVI, and XXVII have been supplied through the kindness of Mr. Fawcett. Plates XIV and XXIV have been reproduced from *Mineral Resources*, 1901, by Mr. E. F. Pittman; and Plate VIII Fig. (b) has been reproduced from the Annual Report of 1897, from a section taken by Mr. J. E. Carne. The diagrams of the Wet Shaft, Goodwin's Pipe, No. 3 Pipe, on M. L. 1 and Nos. 5 and 25 North Pipes, all at Kingsgate, have been reproduced from figures courteously supplied by Mr. Leo Cotton, Acting-Professor of Geology at the Sydney University.

The numerous plans, maps, and figures illustrating the report have been prepared by Mr. O. Trickett; some of the figures being prepared from the writer's measurements by Mr. Kenny, Field Assistant.

The analyses of rocks were prepared at the Departmental laboratory under the supervision of Mr. J. C. H. Mingaye, and the petrological notes were supplied by Mr. G. W. Card, Curator of the Mining Museum.

Magnificent specimens of molybdenite have been donated to the Mining Museum at the request of the Curator and other officers of the Survey and Inspectorial Branch, and these specimens should be studied by all prospectors of molybdenite, who might thus save themselves much needless expenditure of time in the prospecting of insignificant deposits.

Among the finest of these exhibited may be mentioned the donations of Mr. V. Sachs and Miss Speckhardt (from Kingsgate), of Mr. W. H. Yates (from Kingsgate), of Messrs. Hollibone and Parnell (Warrell Creek), of the Whipstick Mines Ltd., of the Yetholme Molybdenite Options, and of Messrs. Boyd Bros., of Mr. Wm. Murphy (Bolivia), of Mr. A. E. Cooper (Bolivia), of Messrs. F. Roberts and F. Heiss (Wunglebung), of Mr. V. Schafer (Booroolong), of Messrs. Baker and Chalmers (Glen Eden), of Messrs. Pedley and Finch (Bow Creek), of Mr. E. A. Baker (Allies Mine), and others.

III.—PROPERTIES OF THE MOLYBDENUM MINERALS AND ORES.

Molybdenum is a white metal with a specific gravity of 9. It is malleable and may be both welded and polished, but it is fused only with great difficulty. It has not been found in the native state; but appears to have been isolated for the first time by P. J. Hjelm, who, according to the "Encyclopædia Britannica" (11th ed.), in 1782 distinguished the mineral molybdenite from lead ore, with which it had been confused previously. Hjelm, also, is said to have discovered the element molybdenum in this mineral.

Ores of Molybdenum.

(1) *Molybdenite.*—The crystals of this mineral are hexagonal, and tabular in form. They may occur also as short and stout prisms with horizontal striations. It occurs, also, in the form of thin plates, masses, or scales, also as grains. Crystals, or massive forms, are separable easily into thin plates in a direction parallel to the base of the crystalline form. The thin plates thus obtained are very flexible but not elastic, that is, they may be bent readily in any given direction, but they do not spring back to their original positions, as micas generally do, when the pressure is released. The mineral may be cut easily with a knife. Its hardness on Moh's scale, is from 1 to 1·5, that is, it may be scratched quite easily with the finger nail. The weight of a given volume of the mineral is from 4·7 to 4·8 times that of an equal volume of water. The lustre is metallic; the colour is lead-grey, and a bluish-grey streak is obtained by rubbing the mineral on white paper. It is opaque, and has a greasy feel.

Its chemical composition is bisulphide of molybdenum, written MoS_2, by which is meant that the smallest portions into which molybdenite may be broken without altering its nature entirely would contain each one atom or particle of the metal molybdenum, to which two atoms of pure sulphur would be found clinging. In pure molybdenite there is only 60 per cent., by weight, of molybdenum, the remaining 40 per cent., by weight, consisting of sulphur.

It has a striking resemblance to graphite, both in softness and general appearance, but it produces a bluer mark on paper, and yields sulphur when burnt on charcoal.

(2) *Molybdite* has a chemical composition known as molybdic acid or oxide, which is written in the form MoO_3. By this chemical formula the idea sought to be conveyed is that the smallest portions to which molybdite may be broken without altering its chemical nature would each contain one atom of molybdenum with three atoms, or particles, of oxygen gas clinging to it. This formula also indicates that in molybdic acid the molybdenum is present to the extent of 67 per cent. by weight, and the oxygen 33 per cent. by weight.

It is a straw-yellow mineral, which occurs both in tufted, hair-like masses, and as yellow earthy incrustations associated with the brilliant faces of the molybdenite.

(3) *Wulfenite* is another molybdenum mineral found in many parts of the world. It occurs also in New South Wales, but is a mineral of rarer occurrence than either molybdenite or molybdite. It is a molybdate of lead, which fact

is expressed in chemical notation by the formula $PbMoO_4$. In this mineral each particle of lead is associated with one of molybdenum, while to them four particles of oxygen gas cling closely. The mineral is, however, frequently impure, containing admixtures, in such cases, of calcium, chromium, and a rare metal called vanadium.

It occurs generally in squarish tables, also in massive form. Its hardness on Moh's scale is 2·75 to 3·0, that is, it is just too hard to be scratched with the finger-nail, but is readily scratched with a knife. It is a heavy mineral, being nearly 7·0 in specific gravity. In colour it varies from yellow to orange, yellow and red; it may also be dark dull green, brown, or almost colourless. The streak is white. The mineral is brittle.

IV.—USES OF MOLYBDENUM.

The salts of molybdenum, in the forms known as ammonium molybdate and molybdic acid, are used in chemical laboratories, to form blue pigments in the manufacture of porcelain, to dye silk and woollen goods, and to aid in the colouration of various leathers and rubbers. In the manufacture of steel in the United States, several tons of molybdenum are used annually in the form of ammonium molybdate as a chemical reagent for the detection and determination of phosphorus in steels. Ammonium molybdate is also reported to be much in demand for fire-proofing purposes, also as a disinfectant for cloth used in passenger carriages on railways.

An important use to which molybdenum compounds may be put is the mixing of same to form stabilisers for high explosives, their presence preventing both deterioration under moderate temperature, and premature explosion in these otherwise unstable compounds.

The great use, however, to which molybdenum is put is in the manufacture of certain steels, as a substitute for tungsten, especially in self-hardening steels, in armour, guns, and other steels needing tenacity and hardness Robert Forrester Mushet, in England, about the year 1858, found out that the introduction of the element tungsten into steel produced a remarkable result in the quality of the resultant product. He experimented on this product till about 1870, and a few years later the old Mushet self-hardening steel was produced, which contained about 1·85 per cent. carbon, 9 per cent. tungsten, and about 2·5 per cent. manganese. In 1900, the University of Sheffield discovered that the elastic limit of steel could be almost doubled without unduly sacrificing toughness and ductility by adding to this Mushet steel a relatively small quantity of vanadium. "By reducing the carbon in the original Mushet steel from 1·8 to 1·7 per cent., much increasing the tungsten and chromium, largely reducing the manganese, and adding 1 per cent. vanadium, the thermal stability of the cutting hardness was easily doubled, rising from 300° C. to well over 600° C. In fact, such steel can be run for several minutes cutting cleanly at a red heat." (J. O. Arnold, "Oxford Pamphlets," 1914–1915. vol. xvi, pp. 11–12.) Modern molybdenum high-speed steel is said to contain from 8 to 10 per cent. molybdenum, about 1·85 per cent. carbon. and about 2·5 per cent. manganese. The results are said to be improved by the addition of a little chromium and vanadium to the mixture. Very heavy cuts can be made with a tool of this steel, and the temper is said to be unimpaired when the tool becomes heated to a high degree, even to dull red heat. One pound of molybdenum is said to go twice as far in the hardening of steel as two pounds of tungsten. ("Mineral Industry, 1909.—Molybdenum.")

Molybdenum steel is also much used for rifle barrels, propeller shafts, heavy guns, armour plates, arc-lamp electrodes, and in the production of other materials. European armour plates are stated to contain up to 2 per cent. molybdenum. If molybdenum could be procured in large quantities it would be much in demand for steel castings for railroad work.

V.—TECHNOLOGY OF MOLYBDENUM.

According to "Mineral Industry,"* two methods are in general use for the reduction of molybdenite from its ores. "The aluminio-thermic process yields a product free from carbon, with small amounts of silicon, and from 1 to 2 per cent. iron. Alloys with chromium and nickel are also made by this process. The electrical process consists in heating the ore in a carbon tube, employing a current of 350 amperes at 60 volts, when a portion of the sulphur is evolved as sulphur dioxide. On increasing the current to 900 amperes at 50 volts, complete fusion is obtained, and the rest of the sulphur is expelled. The metal produced in this way contains about 7 per cent. of carbon, of which about 1 per cent. is graphitic. The whole of this carbon can be removed by heating the crude metal with molybdic oxide."

"At high temperatures molybdenite steel becomes very hard, but when annealed it is softer than tungsten steel."

Molybdenite steel can be tempered in water without showing fissures, and it is said not to break cold short so easily, as does tungsten steel. The Molybdenum employed in steel works is usually in one of three forms:—

1. A dark-blue metallic powder containing 95 to 99 per cent. of molybdenum.

2. Ferro-molybdenum, of which typical specimens contain molybdenum 87·5 per cent., iron 6·4 per cent., carbon 6·3 per cent., or molybdenum 75 8 per cent, with less than 2 per cent. carbon, and the rest iron.

3. Molybdenum nickel containing 75 per cent. molybdenum and 25 per cent. nickel. An alloy with chromium is also made containing 50 per cent. molybdenum.

"Ferro-molybdenum, like crude molybdenum, can be manufactured direct from the natural sulphide in the electric furnace, but made in this manner has a high percentage of carbon. Its refinement requires further treatment with fused lime in the electric furnace, an operation which removes any excess of this element, if necessary, or eliminates it altogether."†

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* 1909, p. 533.

† Dunstan B. Molybdenite. *Queensland Govt. Mining Journal*, July, 1916.

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PLATE I.

View of treatment plant belonging to "Sachs of Kingsgate" Company.

VI.—THE CONCENTRATION OF MOLYBDENITE ORES.

One of the great difficulties attendant upon molybdenite mining is that connected with the problem of concentration. The Molybdenite is very soft and occurs in plates or leaves, and it is associated usually with rocks much harder than itself. If the molybdenite occurs in large flakes these may be secured after crushing by screening and hand-picking. Although molybdenite has a specific gravity much higher than that of quartz, slate, limestone, or other common rocks, nevertheless the crystals split into the finest scales upon slight pressure, and are floated away, during wet concentration, in spite of their relatively-high density.

For the recovery of molybdenite ore in very fine plates, separation by a mixture of water, air or gas, and water, with or without acid, promises to be very valuable. This is due to the selective action of the oil, sometimes in conjunction with acid, on the bright molybdenite particles. The greasy flakes become wet with an oil film, and float, while the gangue material of the pulp, mixed with water, sinks. In this way rich concentrates are produced at various centres.

Methods.

All known methods of saving molybdenite are more or less crude even at present, inasmuch as the treatment of molybdenite is only in the pioneer stage. Much of the ore in the State is crushed and screened dry.

(1.) Small deposits containing molybdenite flakes of moderate size in quartz.

(*a*) The ore is crushed either by means of bucking hammers or by hand rolls. The larger flakes are hand-picked, while the smaller flakes are saved by hand-sieving, the undersize being mainly of the nature of quartz grains.

(*b*) The ore is broken by rolls which are driven by horse power, the horse describing a circle of about 20 feet in diameter with the end of a lever. The ore is reduced to various sizes and sieved.

(2.) Large deposits such as Kingsgate, containing molybdenite and bismuth in a clean gangue of quartz or siliceous granite.

The accompanying description is of one of Mr. Yates' plants at Kingsgate, 20 miles east of Glen Innes.

The capacity is about 5 tons a day, and the cost of the plant erected was about £1,000. Two men and a boy are employed on the plant.

Ore with an average content of 3 per cent. bismuth and molybdenite is hand-fed from a plat to a No. 2 Dodge rockbreaker, and there crushed to pieces about 1 inch diameter. From the rockbreaker the ore passes through two sets of rollers, each having screens to save the large flakes of molybdenite as over-size. This over-size is re-rolled to reduce the quartz to a smaller gauge. Underneath the second pair of rolls a shaking screen is fixed. The holes in this shaking screen are about $\frac{1}{12}$ inch diameter. The undersize passes on to a Wilfley table to save the bismuth, the tailing being stored pending probable improvements in treatment, such as some form of oil concentration.

The oversize from the $\frac{1}{12}$ inch screen is carried to a third set of rolls where it is crushed to $\frac{1}{20}$ inch gauge, and screened. Much of the oversize from this process is cleaned by hand-sieving. The first part of the oversize, however, is re-crushed in rolls set close together, and passed over screens of

$\frac{1}{32}$ inch mesh. The oversize from this varies from 92 to 95 per cent. molybdenite. The undersize is a product rich in molybdenite, but considerably below 90 per cent. fine.

A plant of type similar to this but costing, according to report, about £1,500, has been erected by the Glen Innes Molybdenite Mining Company, on the Old 45, or Sachs' lease. A similar plant belongs to the "Sachs of Kingsgate Company."

A plant with rolls, screens, and other appliances for concentrating the molybdenite dry is employed at the Bow Creek Mine.

In Sydney, Mr. W. G. Gentles employs rolls and shaking tables to recover the molybdenite as a rich concentrate.

(3.) More Modern Plants.

Some method of oil flotation, for the concentration of the molybdenite, appears to be the best process known at present for the treatment of molybdenite ores. As examples of these types the treatment plants belonging to the Whipstick Mining Company, to Mr. Geo. Baker, and to The Sydney Export Company may be selected for description.

Whipstick Plant.

The capacity of the plant is said to be 25 tons a day of three shifts, the cost is estimated approximately at £3,000. The principle of treatment is—crushing in a battery, thence the pulp passes over Wilfley tables and thence into a Mineral Separation Plant. Power is secured by a boiler of 50 horse-power, and various engines. Wood is used at a cost of 13s. a cord. The ore is hand-picked and bagged at the mine, thence it is carted downhill along a steep bush track for a mile and a quarter to the mill, the ore being hand-fed into a 15-head battery of stampers, in three groups of five stampers each, each stamper being about 9 cwt. The material is crushed coarse, about 20 mesh, and the pulp from each battery of five stampers passes over plates on to a Wilfley table, the bismuth forming a thin outer streak which is caught over the end of the tables in a settling pit, the concentrate thus formed being a marketable product. The molybdenite forms the middlings and comes off the points of the tables, where, together with the sands, it passes in launders to a large settling pit, whence it is elevated by an endless belt with cups to a conical tank, from which the sands are drawn off at the bottom end, and sent thence by launder to the mixer of a 12-inch unit of a Mineral Separation Plant. The overflow is conducted by launder to a Dorr-thickener of 100 tons capacity, whence the pulp now dewatered in great measure is conducted to the mixer which is receiving the sands from the Spitz-Kasten.

Oil drops continuously from a drum into the mixer, the consumption of oil being about $\frac{3}{4}$ lb. to the ton of ore treated. In the mixer blades rotate rapidly in a horizontal direction, and set up a continuous agitation of the pulp which is discharged into No. 1 separator through a wide slit protected by an overhanging shutter within the separator. The molybdenite rises as a froth to the surface of the water in the separator and overflows into a launder passing thence to a settling tank from which the excess of water is discharged through a narrow slit. The sands within No. 1 separator are drawn by suction into the box behind No. 2 Separator by means of blades rotating rapidly therein. Thence the process of frothing the molybdenite is continued in No. 2 Separator as it was in No. 1. So also with Nos. 3, 4, 5, and 6 Separators.

The product of Nos. 4, 5 and 6 Separators is conducted by a special launder to the mixer for re-treatment.

The finished product varies from 82 to 90 per cent molybdenite.

Mr. G. E. Baker's Molybdenite Plant.

The capacity is said to be 35 tons a week, running three shifts a day. Power is obtained from electric motors, the electricity being purchased at a flat rate of 1½d. a unit. The principle of the treatment is to crush fine by means of a rockbreaker and rolls, and then to treat in a mineral separation plant with a sub-aëration attachment.

The ore is purchased from various parts of Eastern Australia, and paid for at rates varying with the complexity of the ore and the nature of the gangue.

The ore is broken in a Dodge rockbreaker to half-an-inch gauge. Thence it is reduced to a 40 mesh in rolls. This fine material is then passed on to a circular trommel, the oversize being returned to the rolls and the undersize being dropped to the floor, whence it is elevated as a pulp to one unit of a 6-inch Mineral Separation plant. In the first compartment a set of blades, rotating in a horizontal plane, keeps the pulp continuously agitated, and into which oil is being dropped steadily from a small cask or drum. The consumption of oil appears to be about 1 lb. to each crude ton of ore treated. From the mixer the pulp passes into the first compartment of the separator through a wide slit, protected by an inclined lid projecting towards the outflow. The molybdenite contents in part rise to the surface and flow as a froth over the lip of No. 1 separator into a launder, whence they pass to a pit or tank. Meanwhile, in the box behind No. 2 separator, a set of blades is in rapid rotation, and these, by producing a vacuum in part, draw the pulp from the base of No. 1 separator through an iron pipe into the box containing the agitator; thence the agitated pulp passes into No. 2 separator, in a manner similar to that in No. 1 separator, and the molybdenite froth passes over the edge of the separator into the discharge launder for No. 1. A similar action is carried on in Nos. 3, 4, 5, and 6 separators. The overflow, however, from Nos. 5 and 6 is returned to the mixer for re-treatment.

From the settling pit, or tank, the molybdenite concentrates are hand-fed into a sub-aëration machine, and the molybdenite is said to be concentrated by this machine to a product containing 90 per cent. molybdenite. The sands, containing bismuth and some molybdenite, are drawn off the base of the large flask forming the sub-aëration plant, and sent to a Card table, from which the bismuth leaves at the end and is collected in a pit, while the molybdenite remainder leaves the table as middlings, and is returned to the concentrator.

The products are dried on iron sheets.

The cost of the plant probably is about £3,000. Ore is purchased on assay, the sampling being effected by an automatic sampler.

The Sydney Export Company.

This Company possesses an up-to-date plant at Jones-street, Pyrmont, Sydney. Molybdenite, bismuth, and wolfram ores are treated, but not purchased.

The method with molybdenite ores only is to crush fine and then treat in one unit of a 6-inch Mineral Separation plant, to which a sub-aëration separator is connected. With mixed ores containing molybdenite, bismuth, and wolfram, an electro-magnetic machine is used to separate the wolfram while the molybdenite and bismuth residuum may be treated in the M. S. plant and the sub-aëration machine.

At Wolfram, Queensland, where a very effective process is employed for the recovery of molybdenite in Australia, the tailings from a wolfram-bismuth concentrating mill, all passing 20 mesh, and containing 2 per cent. to 4 per cent. of molybdenite, were treated by passing them over suitable flotation boxes without the aid of acid or oil. The flotation boxes there consisted of a series of cone-shaped boxes, with the usual overflow, the ore being fed on to the water surface by means of an inclined plane, the molybdenite, in the form of a thin scum, passing over the overflow lip, while the tailings were discharged at the bottom of the box. The necessity for a rapid forward movement of the flotation surface involved the use of a somewhat large overflow of water, which was necessarily contaminated with the siliceous gangue of the ore, and this affected the molybdenite concentrate and reduced its assay value.*

At that time a molybdenite concentrate had to contain more than 90 per cent. molybdenite to be saleable readily, and several alterations and additions had to be made before this was possible.

A plant erected by Mons. Charles Poulot at Sheehy's Wharf, Greenwich, Sydney, presents some interesting features. The ore, after fine crushing, is pumped to the top of the building by a sand-pump into a de-watering-tank. Thence the water returns to the pump, while the ore drops into a small centrifugal situated beneath the de-waterer, and within this the ore is mixed. From taps this mixture is dropped into horizontal shaking troughs pierced with holes and discharging into boxes filled with water. The molybdenite floats, and is discharged into launders leading by tubes to a screen of 180 mesh and then dried.

The boxes are arranged in four tiers vertically above each other. As soon as a certain amount of pulp has been treated in the upper tier of boxes, taps are opened in these boxes, and the material which has sunk to the bottom is led into the horizontal shaking troughs attached to the second tier of boxes, and the whole process is there repeated. Similarly for Nos. 3 and 4 tiers of boxes. The process is thus a fourfold one.

Queensgate, Black Range.—The capacity of the plant is not known, no trial having been made up to the time of my last visit to Bega in March, 1916, but the plant appears designed to treat several tons a day of eight hours.

The plant is arranged on a contour, and not on a profile, of the steep hillside forming the southern portion of M.L. 3, Parish Kameruka, County Auckland.

The ore is brought to a platform and fed thence by hand to a Dodge rock breaker, and broken in two stages to a half-inch gauge. This material is delivered to an endless belt with cups which conveys it to a set of Jacques' rolls, by which it is crushed to a $\frac{1}{16}$ inch gauge. The product thus obtained is passed over shaking screens, the oversize from which is discharged into a separate compartment and returned to the rolls, while the undersize is elevated to the mixing vat.

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* The Concentration of Molybdenite Ores. *Mining and Engineering Review*, 6 May, 1912.

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[*Photo by Colin Y. Caird.*]

View of treatment plant at Irvinebank, North Queensland

From the mixing vat, the pulp passes by an endless belt into a long narrow feeder, through the medium of a distributor consisting of a piece of piping, hollow at each end and perforated along its basal length. The feeder in shape is much like a 10 feet length of a launder of rectangular section, closed at each end, and perforated by holes at its base. The pulp from the feeder falls on to an inclined sheet of iron with small corrugations, to a horizontal shaking trough about 10 feet in length, and punched with holes at the base. Thence the pulp flows over a sloping board into the concentrator.

The concentrator is built on the floor, and is formed of compartments separated by vertical walls of concrete, the length over all being 20 feet, the width 11 feet, and the depths of the compartments varying from 3 feet where the pulp flows smoothly from the shaker to the water to 16 inches at the end over which the outflow takes place.

The first trough is about 11 feet long, 5 feet wide and 3 feet deep, this discharges over a lip into a trough 4 inches vertically lower in water level, being 11 feet long, 3 ft. 6 in. wide, and 32 inches in depth. Six of these compartments constitute the concentrator, and the molybdenite is supposed to float on the water surface, and be recovered along various small channels leading from the compartments.

The sands are to be caught in the first compartment and may need re-treatment.

Another plant for the treatment of molybdenite, namely, that for the Elmore Process, has been described in "The Engineering and Mining Journal," 11 May, 1907.

A plant for the treatment of molybdenite was being erected at Deepwater River, Deepwater, towards the close of 1915. This consisted of a jaw-crusher and rolls, which were to feed on to a shaking table, the oversize from which was to be returned to the rolls, while the undersize was to be discharged into a pit, from which it was to be elevated to a ball-mill. The pulp from the mill was to be collected in a pit from which it was to be elevated to a box with revolving blades, the molybdenite being supposed to be driven to the surface and discharged as an overflow into a launder, while the heavier material containing other minerals, such as bismuth, were to be drawn off and treated on tables.

Mr. Nathan Borchardt, of Sydney, has taken out a patent for the treatment of dry concentrates, sands, and the like materials. In the specification which was lodged 16th November, 1914, it is set out that :—"The invention consists, firstly, in a method in which the material to be treated (in a dry state) is subjected to the action of an air-blast which is adopted to carry forward the material and which, while doing so gradually diminishes in velocity so that the particles are deposited in gradation as the velocity of the blast becomes insufficient to sustain them. And the invention consists, secondly, in apparatus for carrying out the before-mentioned method, said apparatus comprising essentially a long tubular flue of gradually increasing cross-sectional area and provided along the length of its bottom with collecting pockets having discharge apertures, means for supplying an air-blast which is introduced into the smaller end of the flue, and means for introducing also into the smaller end of the tube in advance of the air-blast the material to be treated."

VII.—MOLYBDENITE OCCURRENCES OF THE WORLD.

So far as in known to the Writer, all of the important deposits of the mineral under consideration occur in the regions listed herein, although it is probable that molybdenite flakes and crystals occur in many localities not mentioned in the accompanying list. Indeed the great sources of supply, as at present known, are limited to a very few localities, namely, Queensland, New South Wales, and Norway.

A consideration of the geological occurrence of the various molybdenite deposits suggests the similarity of such occurrence the world over.

1. *Canada.*—According to Dr. T. L. Walker,* Canada possesses twelve deposits of molybdenite which promise to repay development. He mentions five types of deposit also in which the molybdenite occurs in Canada:—

"(*a*) Very coarse veins of granite, called pegmatite, often intersect such rocks as gneiss, slate, and quartzite. They contain various minerals of economic value, principally muscovite and felspar. Genetically these veins owe their origin to material derived from large masses of granite, which are usually to be found in the vicinity, and which probably occur at no great distance beneath the pegmatite mass. Molybdenite is occasionally present in these veins in varying quantities, and some of the important ore bodies of Canada are of this type, as, for example, those at Romaine in Quebec and Glengarry in Cape Breton.

(*b*) Many quartz veins have originated in a method similar to pegmatite veins—the fissures have been filled by material derived from underlying deeply-seated granite masses. Some quartz veins are almost free from felspar, others contain so much that it is doubtful which should be designated by the first term and which by the second. In some quartz veins, practically those containing a little felspar, molybdenite is a casual constituent. Examples: Jordan Falls, Shelburne, county N.S.; Mont Cerf, Ottawa, county Quebec.

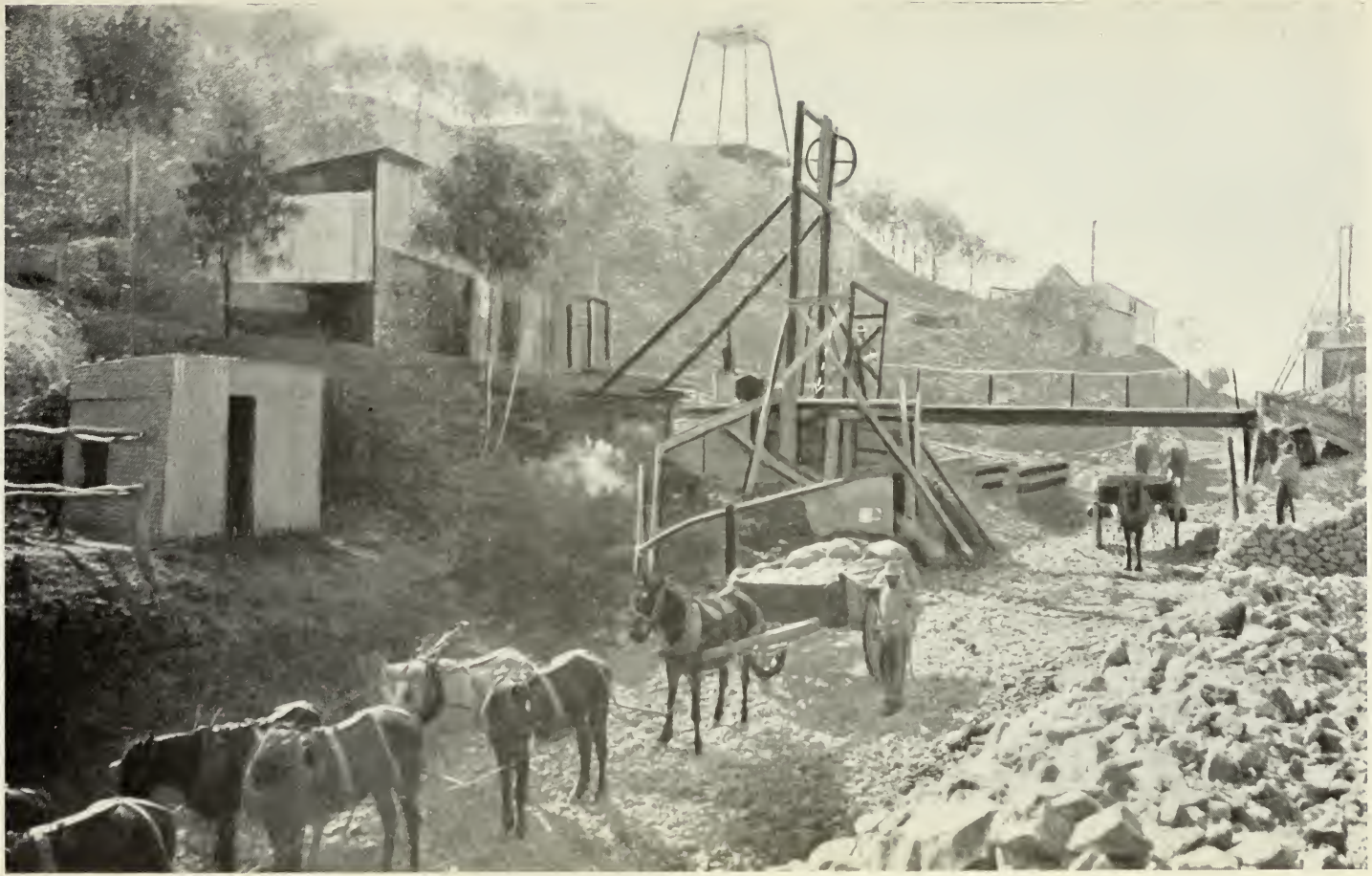
(*c*) In a few instances granitic rock is intersected by series of joint planes along which corrosive substances appear to have travelled. Fluorspar, quartz, and occasionally molybdenite have been deposited, and are also scattered in the granite some distance from the joints. In this way the granite, over considerable areas, may be impregnated with scales and crystals of molybdenite. This type is best represented by the ore bodies at Cooper and Catherine's Hill, in Maine.

(*d*) Another type of occurrence is represented at the Giant Mine, Rossland, B.C., the Marble Bay Mine, Texada Island, and the Hervey Hill Mine, near Broughton, Quebec. In those mines the ore bodies are valuable for copper and molybdenite. The latter mineral is, in both instances, quite massive, and very fine grained.

(*e*) Frequently, very important deposits of molybdenite occur near the contact of intrusive granite or pegmatite with crystalline limestone. These two rocks types appear to have reacted on one another, and a band of greenish pyroxene rock has been formed. In or near the pyroxenite, and frequently in the pegmatite borders, pyrite, pyrrhotite, and molybdenite are to be observed. This type of deposit is frequent in the Ottawa Valley, and is well represented . . . from a deposit in Lynedoch township, Renfrew county."

* Molybdenum ores of Canada. Dept. 93, Dept. Mines, Canada, 1911.

Leisner's Shaft. Larkin's and Wade's Shaft.



Murphy and Gahney's Mine.

[*Photo by Colin Y. Caird.*]

General view of three famous molybdenite-wolfram-bismuth mines in North Queensland.

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Various localities in Canada at which molybdenite occurs are also mentioned in "Mineral Industry" for 1909.* "Ontario is the only province in which the ore has been mined to any extent. A deposit has been worked at Sheffield, Addington county, since 1903. The mineral occurs there with pyrites in a granite country rock, and as mined contains about 4 per cent. of molybdenum. In 1909 deposits of molybdenite were found at Turnback Lake, in the eastern Abitibi District, Northern Ontario, about 3 miles from the Grand Trunk Pacific Railway. . . . . On Kewagama Lake, a few miles to the south-east, there are 7 or 8 square miles of granite outcroppings in which this mineral has been found to occur frequently. On the east shore of the lake the granite is cut by quartz veins containing molybdenite in large crystals."

In 1913, there was no commercial production (of molybdenite) reported in Canada, but in the latter country there was some prospecting activity in Ontario, Quebec, and British Columbia.†

In C. W. Drysdale's report on a deposit, of molybdenite‡ at Lost Creek, Nelson Mining Division, B.C., Canada, he instances molybdenite as having been recorded from twenty localities in British Columbia, from eighteen in Ontario, from fifteen in Quebec, from three in Nova Scotia, from three in New Brunswick, and from one in Manitoba.

2. *Ceylon.*—"Deposits of molybdenite occur in Ceylon at Hettimulla, 4 miles south of Kegalla. A sample examined at the Imperial Institute in 1906, consisted principally of molybdenite, and contained nearly 51 per cent. of molybdenum, but, according to the Progress Report of the Ceylon Mineral Survey, the molybdenite-bearing pegmatite deposit was neither extensive nor rich in the mineral." (Extract from Imperial Institute Circular of 1915.)

3. *Federated Malay States.*—"In the Federated Malay States molybdenite was observed by the Government Geologist in 1905, in a granite quarry near Bukit Panjang." (Extract from Imperial Institute Circular.)

Germany.—"Molybdenite occurs, in small quantities, in quartz and a hard greenish rock in the Erzgebirge on the Saxony side." ("Mineral Industry," 1909.)

India.—"There is no record of molybdenite having been worked in India. It has been observed in small quantity in the Patra River, near Mahabagh, and the Baraganda copper mine at Urmi, near Dumri, Hargaribagh District, Bengal; in parts of Chota Nagpur; in Rajputana and Mandavria, near Kishingarh, and in Burma, on the road from Tavoy to Myitta. Molybdenite also occurs disseminated through the Travancore pyrrhotites, and might possibly be worth separating from the ores, should these ever be worked for copper and nickel." (Extract from Imperial Institute Circular.)

Japan.—"Molybdenite deposits are reported from the provinces of Echigo, Izomo, and Hioa; and the mineral has been exported in small quantities." ("Mineral Industry," 1909.)

Mexico.—"Wolfenite is found abundantly with the lead ores of the Cuchillo Parado Mine in eastern Chihuahua. Some shipments have been made. Molybdenite is reported in several Sonora localities, and in the States of Oaxaca, Hidalgo, and Jalisco." ("Mineral Industry," 1909, p. 531.)

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* p. 531.
† Mineral Industry, 1913, p. 508.
‡ Geology of the Molly Molybdenite Veins. Trans. Canad. Min. Instit., vol. XVIII, 1915, pp. 247–255.

Natal.—Outcrops showing Molybdenum ore occur at Impendhle, at the foot of the Mahotoya Range, Hlatimba River. The ore is said to occur as an oxide impregnation in sandstone beds, which outcrop over an irregular area, the greatest length of which is 3 miles. The material is reported to carry at least 8 per cent. of molybdenum, and another rare element, probably uranium, is present." ("Mineral Industry," 1909, p. 531.)

New South Wales.—The greater portion of the molybdenite from this Australian State is won from New England, in the north-east, and from Whipstick, in the south-east.

The deposits occur as follows:—

A. Pipes, or cylindrical masses of tortuous form.
   (*a*) Quartz pipes.
   (*b*) Pegmatitic do.
   (*c*) Granite do.
   (*d*) "Mica-garnet" do.
   (*e*) "Garnet" do.
B. Aplitic segregations.
C. Pegmatitic veins.
D. Quartz veins containing felspar.
E. Quartz veins.
   (*a*) In greisen within the peripheral areas of coarse, sandy granite.
   (*b*) In aplites or tin-granites of fine texture.
   (*c*) In coarse, basic granites.
   (*d*) In sandy granites, fine and coarse in texture.
   (*e*) Networks of veins in quartz-porphyry.
F. Contact deposits, containing abundant garnet, wollastonite, amphibole, actinolite, quartz, with a little pyrrhotite and pyrites.

New Zealand.—"Molybdenite was discovered in 1898 at the Iron Cap Mine at Tarauru, Thames, where it occurs in pockets and small stringers near an ironstone vein. . . . The ore also occurs at Dusky Sound, on the west coast of Otago, and in auriferous quartz in the Paparoa Range. Molybdenite has been found recently in connection with a copper deposit at Mount Radiant, at the head waters of the Mokihinui and Little Wanganui Rivers. The mineral occurs in quartz and felspar veins, which also carry chalcopyrites and iron pyrites. . . . Wulfenite is known to occur in Dun Mountain, Nelson." ("Mineral Industry," 1909, p. 532.)

Norway.—Molybdenite occurs in small veins in many localities in Norway. An ore containing only half of 1 per cent. of this mineral is being worked at a profit owing to the cheapness of water power in the district.

"The export has, in some years, amounted to 40 tons, with a content of between 90 and 100 per cent. Molybdenite has come from Storknaben, Grube, at Flekkefjord, owned by Messrs. George Blackwell, Sons and Co., and the Albany, near Liverpool." ("Mineral Industry," 1912, p. 599.) The Knaben or Storknaben mine is in the south-west of Norway, and it is reported to have produced from 25 to 30 tons of molybdenite annually since 1902. The ore appears to be concentrated by the Elmore process.

Crystals of molybdenite, 6 inches across, have been reported in recent years from Slangsvold, near Raade, in Norway. (Encycl. Brit., 11th Ed.)

Wulfenite also has been mined near Egersund, and it has been found in hornblende gneiss, in association with copper ores.

Library
of the
University of Illinois

[*Photo by Colin Y. Caird.*]

General view of Wolfram Camp, North Queensland.

Peru.—"Molybdenite has been found in the provinces of Convencion, Huaylas, Canta, Trugillo, Carabaya, Ica, and Aymaraes, but the most important discovery was made in 1901 in the province of Janja, on the Runatullo farm, giving rise to the formation of the 'Sociedad Explotadora de Molibdeno,' organised in Lima."

"Wulfenite was found by A. Raimondi, with malachite and other copper ores, in some mines near Huantajaya, province of Tarapaca." ("Mineral Industry," 1903, p. 532.)

Queensland.—The most important molybdenite producer in the world is Queensland, the State adjoining New South Wales on the north. The geological occurrence of the mineral in this State presents features strikingly similar to those of New South Wales. Nevertheless, whereas the main tin, wolfram, and molybdenite-bismuth, deposits in New South Wales occur in localities and under conditions quite distinct from each other, in Queensland, according to report, the wolfram, molybdenite, and bismuth deposits occur all together, the three minerals occurring together in all the mines. The main tin deposits of Northern Queensland, however, appear to occur separately from the wolfram-molybdenite-bismuth deposits. Very little information is to hand as to any possible or probable difference between the tin and molybdenite granites in Queensland, as is the case in New South Wales. Each great group of molybdenite deposits in Northern Queensland and in New England (New South Wales) appears to be of the same age, namely, closing Permo-Carboniferous.

All the important deposits of the mineral under consideration occur in Northern Queensland.

Townsville Mineral Field, Ollera.—"The wolfram and molybdenite, with appreciable quantities of bismuth and traces of tin, occur in irregular elongated bodies of white quartz at the intersections of certain joint planes in the granite. A great number of these shoots or pipes, generally dipping at high angles, have been exposed, but there is reason to believe from the greisenised condition of the country and the abundant quartz fragments on the surface that a far greater number of pipes remain to be unearthed."*

Speaking of the deposits of molybdenite, bismuth, wolfram, and tin in North Queensland, Mr. Ball writes: "All the deposits occur either on or within a few hundred feet of the contact of the granite and the rock it intruded, exceptions to this rule being only apparent. Thus, when a deposit is found in the granite distant from a covering rock, it is easy to show that the intruded rock has formerly existed at no great elevation above the present surface; and when the deposit is found in sediments unassociated with the granite it can mostly be shown that the latter lies at comparatively shallow depths below the surface.

"The deposits, when occurring in granite, are peculiar in shape, being typically bent and contorted tubes or pipes, the origin of which is not perfectly clear, beyond that they have been produced in the solidifying magma by the escaping gases and solutions. The pipes are frequently, but not always, connected with joints in the rock, and every endeavour was made to prove that the deposits were simply the infilling of discission at the intersections of such joints. The failure of this theory to account for the observed facts was so frequent that its insufficiency had to be reluctantly admitted.

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* *Queensland Govt. Mining Journal*, vol. XII, 1911, p. 564.

"Wolfram, formerly and less ambiguously known as Wolfram Camp, is the centre of the largest field, and is located near the extremity of a large massif. The workings extend without a break for a distance of over 2 miles along the contact of an intrusive granite with older porphyries and slates. . . . . The total production of the field of late has averaged 16 tons of wolfram (and bismuth) and 7 tons of molybdenite per month."*

Mr. Ball furnishes short descriptions of the mines, of which the Larkin, McIntyre, and the Murphy and Leisner are the main producers.

"On the Larkin several irregular pipes have been worked in the greisen beneath the slate contact, and during the past year one of them of small size was followed down to a depth of nearly 100 feet beneath the surface, where accident revealed the existence of an adjacent pipe, which, as since stoped, has a length of 26 feet and a width of 14 feet. . . . . The mine was producing at the rate of $1\frac{1}{2}$ tons molybdenite and $3\frac{3}{4}$ tons wolfram per month.

"The McIntyre lies some distance back from the slate hills. The main pipe . . . . has been followed down on the underlie to a total vertical depth of 242 feet. The diameter of the stopes varies between 5 feet and 30 feet, the average being about 12 feet. The tributers were working small branch pipes on the side of the main shoot at 250 feet down the underlie. . . . . The wolfram and molybdenite occur in elongated bodies or pipes of white quartz, surrounded by a granular quartz rock, believed to be silicified greisen. . . . . Near the surface the pipe pitched flatly, being sometimes nearly horizontal, but in the lower workings the inclination is about 1 in 1.

"The Murphy and Leisner adjoins the Larkin on the slate-granite contact. In the early days a 35-ton patch of alluvial wolfram was found on the Frederick the Great, just outside of this claim, and subsequently a rich ore-body was worked near the Larkin boundary. Still later, a shaft was sunk to the north of the rich surface patch, and bottomed at 70 feet on the rich pipe that has since been exploited.

"During the last three years the mine has produced 150 tons of wolfram, 100 tons of molybdenite, and 4 tons of bismuth. From the shaft the ore was worked out along the Frederick the Great boundary for 100 feet, and then an underlie stope was carried down for 100 feet to the north at an inclination of 1 in 1. Beyond that the pipe seems to be pitching very steeply to the east. The average diameter of the stope is rather more than 20 feet.

"That the ore-bearing pipes occur chiefly, if not wholly, in the greisen of the contact zone is now recognised by the miners, and, as the crop of this zone has long been appropriated, the more far-seeing spirits have begun to peg out the deep ground, the contact dipping flatly out from the granite core."†

South Australia.—Molybdenite is obtained from the North Yelta Mine, at Moonta, about 125 miles northerly from Adelaide. The molybdenite occurs with copper sulphides in such a manner as to have led both Mr. L. K. Ward, the Government Geologist of South Australia, and Mr. Jack, Assistant Government Geologist, to consider the veins to be of igneous origin. This is strongly suggested also by the mere presence of the molybdenite itself, which, in all other localities observed in Australia up to the present, appears to be a mineral which has been derived from granitic vapours near the intrusive

* Lionel C. Ball, Rare Metal Mining in Queensland, *Queensland Govt. Mining Journal*, vol. XIV, Jan., 1913, pp. 4 and 5.

† Lionel C. Ball, *op. cit.*, pp. 5–6.

PLATE V (*a*).

[*Photo L. C. Ball.*]

Deep sinking at Wolfram, North Queensland.
Leisner's Shaft.

[*Reproduced from Queensland Govt. Mining Journal*, 1913, *p.* 4.]

contact of the granite. Moreover, the associated and remarkable copper veins of Moonta and Wallaroo are suggestive of igneous origin, inasmuch as the veins in certain places appear to consist of amphibole and other crystals set in a paste of copper sulphides and other pyrites. The yield of molybdenite from South Australia, however, is negligible.

Sweden.—In the island of Ekholmen, in the archipelago of Westervik, molybdenite has been worked in a hornblende gneiss, associated with molybdite and copper pyrites. The veins carrying the minerals vary from 6 inches to 2 feet in width, and have yielded lumps of pure molybdenite weighing up to 5 lb. ("Mineral Industry," 1909, p. 533.)

Tasmania.—Mention of various molybdenite occurrences in Tasmania is to be found in the accompanying list of official reports :—

No. 1.—Report on Ores of Tungsten and Molybdenum in North-eastern and Eastern Tasmania, by Loftus Hills. 1915.

From this recent report the accompanying notes on Tasmanian molybdenite have been obtained.

No. 2.—Report No. 6. Reconnaissance of the North Heemskirk Tinfield, by L. L. Waterhouse. 1915. Page 22.

No. 3.—Bulletin No. 14. The Middlesex and Mount Claude Mining Field, by W. H. Twelvetrees. 1913. Pages 35, 47, 67, 74, 80, 82, 97.

No. 4.—Bulletin No. 10. The Mount Balfour Mining Field, by L. K. Ward. 1911. Page 49.

No. 5.—Bulletin No. 9. The Scamander Mineral District, by W. H. Twelvetrees. 1910. Page 31.

In discussing the method of occurrence of molybdenite in Tasmania, Mr. Hills points out that it may be looked for in granite country and in the surrounding metamorphic aureole.

"In regard to the form of the deposit which carried the minerals, it may be stated that many widely-different forms are known. Perhaps the most usual is that of quartz veins in both the granite and the surrounding rocks filling the fractures along which the mineralising gases escaped. These quartz veins often persist for considerable distances, 1,000 feet being quite usual, while occasionally much greater lengths are observed, as, for instance, 34 chains at Story's Creek in the Ben Lomond district of this State. The width of the quartz lodes is not very great, the average being from 1 to 2 feet. The constituent minerals are wolframite, cassiterite, pyrite, bismuthinite, and molybdenite, in a gangue of quartz, sometimes with the addition of tourmaline, fluorite, and other minerals. The several minerals occur as independent crystals or masses in the quartz, intimate intergrowth of any two of the minerals being almost unknown, although they may occur in contact. . . .

"Another type of deposit is that of pegmatite veins or dykes, which consist of coarse aggregates of quartz and felspar, carrying the metallic minerals in bleb's and patches, each mineral species generally occurring in separate crystalline aggregates. . . . . It remains to mention a rather exceptional occurrence of molybdenite in normal biotite granite as an original constituent, crystallising from the magma along with the quartz, felspar, and mica of the normal granite. The molybdenite in this case occurs as small patches in the granite, intergrown with the other components, and very sparsely scattered throughout the granite mass. Such is the mode of occurrence on the greater part of the western slopes of Mount Stronach, near Scottsdale, in this State. It does not seem as if this class of occurrence is of any economic importance, the molybdenite being scattered throughout too large an amount of rock."

Localities in Tasmania.—As cited by Messrs. Twelvetrees, Ward, Hills, and Waterhouse. " Fluorite-topaz-quartz veins of the S. and M. Mine at Moina (tin, wolfram and bismuth), which traverse a magnetite-garnet-vesuvianite rock (an altered limestone) a little molybdenite is found." (Twelvetrees, personal communication.)

" Lady Barron Mine, Moina (wolfram-quartz vein), Gurr's mine and Dolcoath Mine (felspar-quartz-topaz rock) contain molybdenite (Twelvetrees).

" On Lorinna Road as scales in fine-grained granite " (Twelvetrees).

Balfour Field.—Molybdenite in quartz veins (L. K. Ward).

Heemskirk Tinfield.—Molybdenite in quartz-tourmaline stone (L. L. Waterhouse).

Mount Stronach.—Small molybdenite crystals occurring as original constituent of granite, but forming only a small fraction of 1 per cent. of the rock. At Harvey's claim the mineral is associated with chalcopyrite and pyrite (Loftus Hills).

Lottah District.—As small flakes and patches in a tin granite (Loftus Hills).

Constable's Creek and Upper Scamander.—Lodes of quartz containing wolfram and molybdenite in contact metamorphic aureole. Area containing lodes about 4 miles in length. Lodes average about 24 inches in width. Very little work done. Prospecting warranted (Loftus Hills).

Story's Creek.—Ben Lomond District. Quartz veins in granite containing wolfram, tinstone, bismuth, molybdenite, and pyrite. The veins are of great length and they vary from 1 ft. 6 in. to several feet in width (Loftus Hills).

Union of South Africa.—Outcrops showing molybdenite ore occur at Impendhle, at the foot of the Mahotoya Range, Hlatimba River, Natal. A sample of ore from the Buschveldt District, Transvaal, examined at the Imperial Institute in 1906, contained molybdenite. Wolfenite has been found in small quantities in the Transvaal silver mines, Leydsdorp District. It is considered likely that molybdenite may occur in the vicinity. (Imperial Institute Circular.)

United Kingdom.—In the British Isles molybdenite has been met with in the Cornish copper and tin mines, but usually not in paying quantities. It is stated to have been worked in Inverness-shire. It occurs at the Mount Sorrel quarries of Charnwood Forest, Leicestershire. (Imperial Institute Circular.)

It occurs as large crystals with wolframite and scheelite in quartz veins at Caldbeck Fells in Cumberland. (Encycl. Brit. 11th Ed.)

Victoria.—The accompanying notes on the occurrence of molybdenite in Victoria (the State in Australia adjoining New South Wales immediately to the south) are extracts from a personal communication by Mr. H. Herman, Director of the Geological Survey of Victoria.

" In every case the mineral occurs in granite or rocks of allied type either in the rock itself or in quartz lodes or irregular quartz veins therein. . . . Up to the present not any of the deposits have had sufficient prospecting or development to warrant the erection of a treatment plant."

Wangrabelle, East Gippsland.—The molybdenite occurs in a quartz lode associated with a dyke, intruding the surrounding granite rocks.

Simmon's Gap, Bright.—The quartz veins carrying molybdenite occur in granite rocks close to their contact with Ordovician beds.

PLATE V (*b*).

[*Photo L. C. Ball.*]

The Murphy and Leisner Mine.
One of the world's greatest molybdenite producers.

[*Reproduced from Queensland Govt. Mining Journal*, 1913, *p.* 4.]

Everton, South of Beechworth.—The molybdenite occurs in irregular quartz veins in granite and in the granite rock itself, close to the contact with rocks probably of Ordovician age.

Mount Stanley, Beechworth.—The quartz lodes carrying the molybdenite occur in granite, on the top of the mount and near the Ordovician contact west of Mount Stanley. The ore occurs also in the granite adjacent to the lodes.

Mount Moliagul, Dunolly.—The quartz lodes with molybdenite are found in quartz close to the Ordovician contact.

Mount William, near Ararat.—The quartz veins carrying the molybdenite ore occur in quartz-porphyry in the southern portion of the field, and in joint planes in quartz-mica-diorite in the northern portion of the field.

Virgin Islands, West Indies.—"Specimens of minerals from an abandoned copper mine at Virgin Gorda, Virgin Islands, were examined at the Imperial Institute, and found to contain molybdenite and molybdenum oxide. One sample represented material which would be worth concentrating if large quantities of the ore were available for treatment." (Imperial Institute communication.)

Western Australia.—A few deposits of molybdenite have been recorded from the very old rocks of this State. As far as can be ascertained, the deposits are not known to have yielded ore for export.

VIII.—PRODUCTION OF MOLYBDENITE IN AUSTRALIA.

THE greatest portion, by far, of the world's supply of molybdenite up to the present has come from the two contiguous States in the more north-eastern portion of Australasia, namely, Queensland and New South Wales. The quantity derived from Norway may be comparable with that from New South Wales.

Year.	Queensland.		New South Wales.	
	Tons.	Value.	Tons.	Value.
		£		£
1900	11	561	.....	.....
1901	26*	1,609	.....	.....
1902	39	5,329	15	1,841
1903	10	1,320	29	4,458
1904	21	2,673	25·25	2,726
1905	63	8,463	19·40	2,507
1906	106¼	15,275	32,65	4,798
1907	66¾	8,442	21·65	3,564
1908	89	9,230	3,45	929
1909	93¾	9,268	28·15	3,249
1910	106	12,050	47·50	5,667
1911	99½	13,278	20·65	2,591
1912	102⅝	17,349	56·55	3,706
1913	66⅓	19,001	78·80	6,802
1914	77¾	38,190	61·40	11,451
1915	97½	45,060	31·70	16,937
1916	.....	.....	.....	.....

* This includes some wolfram and bismuth.

The production of molybdenite in Australia during 1916 appears to be at the rate of 11 or 12 tons a month, approximately, till the end of July, 1916. Queensland has produced about 70 per cent., and New South Wales about 25 per cent. in value of the world's supply of molybdenite.

PLATE VI.

[*Photo L. C. Ball.*]

Top Camp, Wolfram, North Queensland.
Hillside workings on left. Tally and Hughes' in mid-distance.

[*Reproduced from Queensland Govt. Mining Journal*, 1913, *p.* 4.]

IX.—GENERAL GEOLOGY OF MOLYBDENITE DEPOSITS IN NEW SOUTH WALES.

A. Granites Associated with Deposits. Preliminary Remarks.

(*a*) General type.
Characters—Coarse, sandy, and granular. 70–73 per cent. silica.

(*b*) Wolfram granite.
Coarse, sandy. 74–80 per cent. silica.

(*c*) Tin and tin-wolfram granites.
Aplitic or porphyritic. 74–80 per cent. silica.

(*d*) Rocky River granite.

(*e*) Basic granites.
Coarse, porphyritic, dark, much hornblende and sphene. Intimately associated with tin-wolfram type where molybdenite occurs in it.

All the molybdenite deposits of New South Wales are associated intimately with granites of varying ages. Certain types of these appear to contain the great majority of the important pipes, others contain small veins of quartz or pegmatite associated with minerals such as tin; others are associated with true white-quartz veins; while others again have small flakes of molybdenite scattered irregularly throughout their mass.

(*a*) *General Type.*—This type includes the famous deposits of Kingsgate, of Whipstick, of Bow Creek (Deepwater), and of Bolivia at the head of Splitter's Creek.

In hand specimens it is typically coarse, granular, non-porphyritic, siliceous, and homogeneous. The silica content is about 72 per cent.

In the field it appears as areas of low-relief relatively, being surrounded by hills, in the districts under consideration, formed of more resistant rock types, such as tin and wolfram granites, altered Palæozoic sediments, or quartz porphyries. Unlike many other granites in New South Wales, especially of the wolfram type, it possesses very little marginal development of aplite and greisen, the intrusive junction of this type with other rocks is very decided, and may be traced with ease across the country by the geologist. There is also a freedom from the dense and scrubby plant growths so characteristic of the wolfram and tin granites.

The more common plant-growths on granites of this type at Bolivia, Deepwater, and Kingsgate, are the red gum (*Eucalyptus tereticornis*), the stringybarks (*E. eugenioides*, *E. macrorrhyncha*, *E. capitellata*), white peppermint (*E. Bridgesiana*), white gum (*E. rubida*), the true white gum (*E. viminalis*) being much less common, messmate (*E. obliqua*), honeysuckle (*Banksia*), wattle (*Acacia decurrens*, *A. dealbata*), black oak (*Casuarina suberosa*), together with broad-leaved apple (*Angophora subvelutina*), and some dogwood (*Jacksonia scoparia*).

Near the coast, as at Whipstick, this type of granite is clothed thickly with immense forest trees, such as mountain ash (*Eucalyptus Sieberiana*), cut-tail (*E. fastigata*), stringybarks (*E. eugenioides*, *E. Muelleriana*, *E. obliqua*), ash (*E. Delegatensis*), peppermint (*E. amygdalina*), white gum (*E. viminalis*), blackwood (*Acacia melanoxylon*),and thick growths of *Acacia longifolia* and *Acacia stricta*.

In this type also the molybdenite deposits occur usually as pipes of quartz, granite, pegmatite, or garnet-bearing material, arranged within a short distance from the intrusive (granite) contact.

The age of the Whipstick type of granite is post-Devonian and pre-Permo-Carboniferous, while that of Kingsgate, Deepwater and Bolivia types is late or closing Permo-Carboniferous.

(*b*) *Wolfram granite.*—This is typically a coarse, non-porphyritic, and very siliceous rock, which is recognised in the field, in the first place, by its striking topographic relief, forming high plateaus rising above other high plains, excavated in the less-resistant blue-granites, molybdenite granites, and basic granitoids of the same districts. In the second place it may be recognised by the dense undergrowths of plants, especially shrubs and undershrubs, belonging to genera or groups peculiarly Australian. In the third place it may be recognised by the fact that it is accompanied in places near its margin by peculiar masses or mantles of aplites, greisens, or other peculiar and variable types of granite, whose texture and mineral composition vary from point to point, and are peculiarly disconcerting to students of limited experience in granites.

The silica percentage is very high, reaching as much as 76 to 78 or even 80 per cent., and the type merges insensibly into the tin-granite type of New South Wales.

The number of plant species on the large and numerous plateaus composed of this dense sandy granite is almost legion, and they vary in some degree according to the position of the plateau, whether coastal, or whether within the eastern, central, or western portions of the main tableland region of the State. Within the plateau of New England at an elevation of 3,000 to 4,500 feet above sea-level, the more characteristic plants are :—Stringybarks (*Eucalyptus eugenioides*, *E. macrorrhyncha*, *E. capitellata*), brown gum (*E. Deanei*), blackbutt (*E. Andrewsi*), cabbage gum (*E. Bancrofti*), white peppermint (*E. Bridgesiana*), white gum (*E. rubida*), black oak (*Casuarina suberosa*) in dense thickets, tea trees (*Leptospermum*) of various types, bottlebrushes (*Callistemon*), *Boronia* of various types, wild daphne (*Brachyloma daphnoides*), dogwood (*Jacksonia scoparia*), dead finish (*Cassinia*), geebungs (*Persoonia*), five-corners (*Styphelia*), ten-corners (*Astroloma*), honeysuckle (*Banksia*), flannel flowers (*Actinotus*), Christmas bells (*Blandfordia*), hickory (*Acacia penninervis*), other wattles (*A. nereiifolia*, *A. rubida*, *A. stricta*, *A. fimbriata*, *A. falcata*, *A. decurrens*, *A. dealbata*, *A. longifolia*, *A. myrtifolia*, &c.). These and many other types grow together on this class of granite, all bearing a more or less stunted appearance, but crowded together so closely as to make cross-country riding very difficult in certain places. For a much more detailed description of the botany of this interesting granite type, the reader is referred to a paper by Mr. R. H. Cambage.*

These granites are scattered throughout New England and occur also in south-eastern New South Wales. Examples are the great and desolate Mole Tableland and Boonoo Boonoo areas, as also the Main Divide from Wallangarra to Stanthorpe, the granite plateau near and along the Main Divide east of Deepwater, Moogem, and probably the Guy Fawkes granites.

In these the molybdenite deposits are unimportant, being confined to veins of quartz and pegmatite, usually with wolfram or tin, and commonly associated with abundant greisen.

* Notes on the Native Flora of New South Wales. Part VI, Deepwater to Torrington and Emmaville. Procs. Linn. Soc. N.S. Wales, vol. 33, 1908, p.p. 45–65.

These granites in New England all appear to be late or closing Permo-Carboniferous in age.

(c) *Tin-granites and aplites.*—In the field these are generally recognised by their relatively great topographic relief, their variability of texture, their peculiar rock associations, and the dense scrubby nature of the vegetation.

It will be found that the tin granites are intrusive into coarse, granular, and porphyritic basic granitoids, which latter make park lands forming a portion of the lower plateau areas which in turn end abruptly against the higher, rugged, and scrubby tin granites.

Such associations of older basic granitoids forming the lower plateau surfaces and intrusive siliceous types forming the higher plateau levels, or residuals, are to be found north of Emmaville, where the Mole Tableland tin and wolfram granite rises above the general level of the New England plateau, which in that region is formed of "blue granite," molybdenite granite, and other rock types; at Oban also where the high plateau residuals of the tin granites overlook the general plateau level to the south, which has been excavated in basic granites as well as the level to the north excavated in the slate and molybdenite granite of Kingsgate; at Wilson's Downfall where the rugged Main Divide which is formed of tin and wolfram granite types, overlooks the plateau of Wilson's Downfall and Undercliffe, excavated in basic granites and granodiorites. At Booroolong also, the tin granite (carrying molybdenite) forms high plateaus associated with basic granite. The tin granites of Bald Nob district both intrude and form plateaus overlooking the broad valleys excavated in the basic Glen Elgin granites. Other localities might be cited, as for example Tingha.*

A peculiar feature connected with the tin granites is that they are usually associated with segregations and intrusions of a very siliceous granite or aplite, usually granular and of very fine texture. These segregations and intrusions may be in the form of aplite veins, pegmatite veins; they may be of the nature of a central mass of variable size, from which radiate tongues and dykes of the same material; or they may take the form of large irregular segregations or developments along the coarse granite marginal areas. In the great majority of these younger masses of fine texture, the rocks contain innumerable small cavities of irregular shape, generally occupying the centre of a nest or small knot of pegmatite of rather fine texture. With these rock types quartz veins with, or without, felspar crystals and pegmatite veins, are usually associated. These quartz and pegmatite veins may occur in the coarse granite, the finely-textured masses of irregular shape or in the sediments or older granitoids or other rocks intruded by these tin granites. Characteristically, however, they are developed near the intrusive margins.

Although these granites are typically tin-bearing in New South Wales, as well as wolfram-bearing in the majority of cases, nevertheless they do not contain notable proportions of either molybdenite or bismuth. Small veins of quartz may contain molybdenite flakes, and the intrusive aplites and granites of octopus shape, or the segregations of aplite or pegmatitic granite, all containing the very small irregular cavities or vughs, may contain scattered flakes of molybdenite, but no molybdenite deposit of this nature as yet has been worked at a profit excepting as small prospector's claims.

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* E. C. Andrews and J. C. H. Mingaye. Records Geol. Survey, N.S. Wales, vol. VIII, p. 223.
J. E. Carne. The Tin-mining Industry of N.S. Wales. Mineral Resources, No. 14, 1911, pp. 22, 23, 63.
Leo Cotton. The Tin-deposits of New England. Part I. Procs. Linn. Soc. N.S. Wales, pt. XXXIV, 1909, p. 743.

(*d*) *Rocky River granite.*—This falls actually under the head of the wolfram granites, but is singled out for special mention here because of the peculiar association within it of large quartz, granite, and pegmatite pipes containing wolfram, molybdenite, and bismuth.

The granite is coarse, granular, very siliceous, and has a well-developed mantle of fine texture in one or two places along its border.

(*e*) *Basic granites.*—Although the great majority of the molybdenite deposits of New South Wales are associated intimately with siliceous granites, nevertheless, true quartz veins containing molybdenite occur in basic granites at Attunga, Moonbi, and the Bega district. In each case the basic granite containing the molybdenite occurs in association with the irregular masses of aplite pegmatitic materials described under the tin-granites.

These peculiar basic types both in New England and Bega produce park lands, and they consist essentially of a coarse porphyritic rock, in which stout hornblende, black mica, and white felspar are conspicuous. Large porphyritic crystals of pink felspar are common in the New England types, and crystals of sphene quite visible to the naked eye are also common. It is probable that this mineral occurs also in the Bega type. At Bega, however, only one quartz vein containing molybdenite has been prospected within the basic granite itself, the remaining of the quartz veins occurring in a very siliceous granular granite, which may be either a marginal phase of the basic type or an intrusion near the margin.

B. Types of Molybdenite Deposits in New South Wales.

(*a*) Pipes.
  1. Quartz pipes—Position, form, mineral association.
  2. Pegmatite pipes.
  3. Granite pipes.
  4. "Mica-garnet" pipes.
  5. "Garnet" pipes.

(*b*) Pegmatite and aplitic segregations.

(*c*) Pegmatitic veins.

(*d*) True quartz veins.
  1. In greisen lying between granite and intruded rock.
  2. In tin granites of fine texture.
  3. In coarse basic granites.
  4. In sandy granites, fine and coarse in texture.
  5. Networks in quartz-porphyry.

(*e*) Contact deposits.
  Molybdenite in limestone, claystone, and quartz-porphyry, altered to actinolite, garnet, wollastonite, and quartz.
  Gemalla and Yetholme localities. Red Rock, Duckmaloi.
  Comparison with contacts recorded from Queensland and Canada.

(*a*) *Pipes.*—The great majority of the important deposits of molybdenite known to exist in New South Wales consist of pipes. This does not imply that all the large deposits of molybdenite occur as pipes. It simply implies that, up till the present time, the mining community in this State has found no deposits of ore other than in pipes, from which considerable quantities of stone have been obtained possessing a degree of molybdenite concentration sufficient to repay the expenses of mining and treatment. It is admitted here that the amount of molybdenite contained in the deposits of Yetholme, Booroolong, Tantawanglo, Glen Eden, Laura Creek, and other places, is very

great, but no profitable mining operations have been conducted on such deposits. Such deposits could only be worked at a profit by the introduction of excessively cheap conditions, coupled with the greatest skill and economy.

Pipes in New South Wales may be of many shapes, but, typically, they have the appearance of tubes filled with quartz, granite, and other material; such tubes, however, being irregular and tortuous in general appearance. They occur within granite masses, close to the intrusive contacts of the latter with other rock types, and although there is no general direction in which they underlie, nevertheless, in very many cases their general underlie or dip is in the direction of the nearest intrusive plane of granite contact.

The pipes consist mainly of quartz, pegmatite granite, or garnet-bearing granite.

1. Quartz Pipes.—By far the finest types of these occur at Kingsgate. For illustrations the notes on Kingsgate should be consulted

Deposits of this nature have a peculiar and broken appearance, a modification of the " step-and-tread " form, which suggests that these peculiar types have been controlled by structural planes in the parent rock, such planes being either visible or invisible to the naked eye. On the other hand, the quartz mass of the pipes suggests the filling of open tubes by quartz.

In this connection there are several facts, which should be remembered.

In the *first* place, the direction alone of a typical quartz pipe may be considered. Sachs', or the Old 45, pipe may serve as an example. In exploring this deposit a cylindrical mass of tortuous habit was followed for a considerable distance in a direction which conformed generally to that of the granite and slate contact in the vicinity. Thence the pipe appears to have been followed in a direction approximately horizontal for a few yards. Beyond this, for a distance of 100 feet, the pipe was followed in a direction paralleling the granite and slate contact. It was on this slope that the famous bulge occurred which yielded so much rich molybdenite. At the bottom of this bulge the pipe was only about 18 feet from the slate contact, and the pipe, whose slope had been but little above 30 degrees from the horizontal above this point, appeared to contract at the point from a width of 20 or 25 feet to about 18 inches, and to descend quite vertically through a distance of 30 feet, thence it was horizontal for a distance of 25 feet. Here the pipe was still small, probably about 4 feet in diameter, and it was followed vertically for 15 feet. On a moderate slope it was then followed for a short distance, where it appeared to split into branches, each about 3 or 4 feet across, and each dipping towards the contact of slate and granite.

This peculiar form, which is suggestive somewhat of the " step-and-tread " arrangement, is instructive when considered in connection with other points.

Thus, both in this and some other pipes in New South Wales, there exist sheets, or very flat lenses, of quartz and granite carrying molybdenite. These may occur as spurs from the main pipe, or as planes whose main trend coincides with that of the pipe itself, and which either sit almost on the pipe itself or alongside of it, or exist as planes arranged vertically to the main axis of the pipes and extending only to short distances from the main body.

All these forms are indicative of the influence of planes of weakness in the granite, along which the vapours of the consolidating and cooling granite arose and formed replacements at intersections of certain planes. This opinion is strengthened after an examination of all the pipes known in a vast district such as New South Wales. Thus, in certain pipes at Kingsgate, such as the Monkey Shaft, the surface workings suggested the existence of a

true quartz vein which, however, was followed downwards into a pipe. At the Rocky River, 26 miles south-east of Tenterfield, Petrie's pipe outcropped more in the nature of a vein than as a pipe. At No. 2 pipe, Bow Creek, Deepwater, the pipe appears (Pl. IX) to have its main axis on a plane dipping to the north or the north-north-west. At Timbarra, in the extremely siliceous granites of closing Permo-Carboniferous age, several of the "gold-pipe" formations appear as bulges arranged along a vein of moderate width.

In this connection, a very interesting occurrence from Maryland, north of Wilson's Downfall, may be mentioned. In the deposit under consideration, which is known as Staine's Lease, the molybdenite occurs as flakes of moderate size in a coarse, siliceous granite near its junction with a still more siliceous type (tin-granite). At first sight the molybdenite appears to be scattered at random throughout the unaltered granite, nevertheless, upon closer inspection, it may be seen to be associated with very small flakes of secondary mica, both at the intersection of tiny joints and along the joints themselves for a considerable distance from their intersections (Fig. 1).

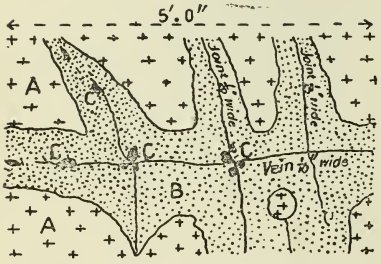


Fig. 1.

Sketch plan of portion of Staine's molybdenite deposits, Maryland (Wilson's Downfall). P.M.L. 1, parish of Ruby, county of Buller.

A.—Coarse siliceous granite.
B.—Granite discolouration.
C.—Molybdenite crystals formed along tiny veins and joints in granite. Some of the joints do not exceed $\frac{1}{50}$ inch in width.

Quartz is also associated with the molybdenite in these tiny joints near their intersections. Several of them were traced from their intersections to points at which the naked eye could distinguish them no longer as joints, nevertheless, their existence could be inferred safely because flakes of molybdenite were found arranged vertically in the granite in such manner that the plane of the joint must pass through the entire vertical planes of each molybdenite flake along that direction. Around these tiny joints also the granite is darkened for widths (Fig. 1) varying from 1 to 10 inches. This discolouration appears to be due to an oxidation of iron pyrites which had been introduced into the granite along the joints, within which the quartz and molybdenite travelled also.

This suggests an initial stage in the formation of a pipe.

In the *second* place, if the structural control of the granite be admitted for the present, as suggested by the notes presented herewith, there arises the question :—"How is it that the assumed joints, at whose intersections the pipes have been formed, are so rarely in evidence?" On the assumption of origin by replacement or other means working outwards from small beginnings at the intersection of joints is it not a condition to be expected that bodies of a magnitude such as the Kingsgate types should be formed along the joints of greatest size in the granite periphery? On the other hand, the large master joints, into which the granites containing the pipes are divided, do not seem to have any direct connection with the formation of the pipes. Furthermore, if it be assumed that the pipes do depend for their existence upon certain activities which moved along granite joints, then such joints must have been very ill defined, inasmuch as they are invisible to-day outside the boundaries of the pipes, at least so far as can be ascertained up to

the present by an examination of the workings. In very rare cases, however, such as at Bow Creek, the pipes are arranged along a zone of numerous and tiny discontinuous quartz veins.

In discussing this point it may be pointed out that the molybdenite pipes appear to have been formed before the great master-joint systems were made in the granite. An examination of the numerous and peculiar deposits under consideration in the molybdenite granite suggests that such were formed during the early consolidation and cooling stages of the granites, while the present system of master-joints were non-existent, while the granites in fact were only beginning to form planes of relative weakness. The molybdenite-quartz appears to be a product of vaporous action, which, under great heat and pressure, has a power of penetration almost incredible. An example of this high penetrative power of molybdenite vapours has been cited on an earlier page in the description of Staine's Lease at Wilson's Downfall. Had there existed great systems of powerful master-joints in the granites prior to the formation of the molybdenite deposits they would doubtless have been utilised by the escaping vapours.

In the *third* place, the filling of a quartz pipe as at Kingsgate, Wunglebung (Rocky River), or Whipstick, is not of a simple nature such as the casual visitor might be led to expect. It might be thought, perhaps, that there is a sharp plane or surface of demarcation between pipe and enclosing granite but such is not at all the case. On the one hand, on the assumption that the molybdenite vapours or solutions had punched or drilled their way upward through the solid granite, or that they had filled large cylindroidal chambers in the consolidated and cooling granite, the walls should have been well defined owing to the shrinkage of the ore deposit upon cooling. On the other hand the pipes in cross-section only approximate to a geometrical figure when viewed as a whole; they are usually irregular in a marked degree; spurs are found here and there, while bulges and excrescences break the regularity of form at all points much in the same manner as may be seen in deposits recognised as of replacement origin. The pipe material is also "frozen-onto" the country, to use a miner's term; it is interlocked with the crystals and grains of the granite country; it appears to have anchored itself into the enclosing granite and its general appearance near the periphery is such as to suggest an influence which had been corroding the country rock with varying strength in radial directions as within parallel planes arranged at right angles to an elongated axis.

In the *fourth* place it may be advisable to consider what light is to be thrown on this interesting subject by a consideration of the mineral composition of the quartz pipes.

In the earlier days of Kingsgate mining the molybdenite content of a deposit was considered to be an impurity, bismuth being the only mineral worked. In this way it was noted by the prospectors at an early stage that the bismuth content occurred within that portion which formed the lowest part of any cross-section of the pipe taken at right angles to its length. In other words, if the pipe were an empty space in the form of a great inclined cave or tube, and if a stream of water about 12 inches in depth should be discharged in this empty cavern, then the positions occupied by the stream in flowing down the pipe would be those in which the principal bismuth content might be expected. The Kingsgate miners called this portion of the pipe its "gutter"; they called that portion of the pipe in the vicinity of the gutter the "footwall," while for the portions of the pipe lying above

the centre they reserved the name "hanging wall." In some large pipes at Kingsgate the "gutter" only is worked, the hanging wall portion in many cases being considered to be unproductive. In some cases a "rise" may have been made to sample the mass of the hanging wall, but its bismuth contents, according to the testimony of trained prospectors, such as Messrs. W. and H. Marshall, is generally negligible as compared with that of the "footwall" side.

The molybdenite content may lie all round the pipe, but it occurs usually, in greatest quantity, above the bismuth. The central portion of the pipe does not appear to be so productive as the more peripheral portions.

If such a pipe be examined in cross-section from footwall to hanging wall, it would be found that the granite country has been altered just below the footwall, the felspars being replaced by nests of hydrous mica, while in the footwall itself whole masses of this mica, soft and yellowish in colour, may be found. Granite would also be found in which the felspars had been replaced, first by certain products, then by mica, and this mica, in turn, by quartz, the original granite having been changed at this stage to a tough and granular quartzite. The footwall of the pipe would consist typically of tight, granular, and interlocking quartz, of a dark colour, containing grains and massive crystalline native bismuth. Above this the quartz would be tight, dark, and massive, with numerous small vughs showing portions of crystalline quartz, with bismuth and molybdenite. Above this much cairngorm is developed, typically crystalline in many places, and carrying little bismuth. Above this again, massive and crystalline quartz is commonly found. The quartz may be white, massive, and brittle, or it may be in the form of huge crystals whose pointed ends project into large cavities. Quartz crystals also may lie in the cavities or may occur in the solid massive quartz. These crystals may vary in weight from a fraction of an ounce to 300 or 400 pounds, while they occur as forms closed by pyramids or points at both ends. The cavities mentioned here may be as much as 12 to 20 feet in length and several feet high besides being of considerable width. The hanging wall consists generally of massive quartz containing nests of secondary mica, which in many places is clearly a replacement of the felspar of the country mica.

The core of crystallised quartz, with or without cavities, might be considered thus by some to be a result of a gradual replacement by vapours working radially in parallel planes arranged at right angles to an elongated axis, the earlier stages of the replacement consisting in breaking up the felspars to mica and other products and the final stages consisting of the formation of crystalline and crystallised quartz, with or without the production of large cavities.

In the *fifth* place it would be advisable to see what light may be shed on this subject by a study of any pipes at Kingsgate showing peculiar properties. No. 35 pipe, on Portion 100, within Yates' Blocks, and known as the Granite Pipe or Shaft, had a greatest depth as worked in 1915 of about 130 feet. The pipe is large, having a maximum width of 13 or 14 feet. The slope is steep and regular. For a depth exceeding 100 feet the gangue of the bismuth and molybdenite is a *granite* in which the felspars either contain a considerable amount of mica or allied material or have been replaced by nests of secondary mica flakes, and in which also a considerable amount of silicification has occurred. At a depth greater than 100 feet, the pipe has split into two, one branch being granite, the other being a small pipe of quartz with altered granite for a collar.

A couple of other granitic deposits occur in the locality.

This occurrence at Kingsgate certainly does suggest that the quartz pipes have gone through phases such as that which is exemplified by the present appearance of the granite pipe in its upper portions.

In the *sixth* place it would be advisable to see what light is to be thrown upon this interesting subject by a mention of certain features in some pipes other than at Kingsgate. The deposits chosen in this connection are the Bow Creek pipes at Deepwater, Cooper's, Key and Parry's, and Murphy's mines at Bolivia, the Timbarra gold pipes, the Rocky River, and the Whipstick pipes.

Bow Creek (Deepwater).—At this place several pipes appear to outcrop within a siliceous zone where the granite has been traversed by innumerable narrow quartz veins, short in length individually, but overlapping and forming thus a belt of considerable width and length. The pipes developed along this appear to consist of an extremely siliceous granite or series of felspar crystals set in a base, or paste, of quartz. Large patches of crystallised quartz also occur as discontinuous cores following the pipe downwards, and the impression gained from the field examination is that silicification has ensued along a zone in the granite, with local intensity of alteration to silica at the intersection of certain zones, and that a greater intensity of silicification would have resulted in the formation of quartz pipes.

The Allies Mine affords a similar example of such action.

Bolivia.—Cooper's Pipe, at the head of Splitter's Creek, is not well defined like the quartz pipes of Kingsgate. The gangue has the appearance of a granite which has been silicified, and the felspars in numberless examples have been converted into soft secondary mica of yellowish colour. Bunches of coarse pegmatite occur in places in the pipe and a small discontinuous core of quartz occurs. Speaking from memory, this quartz development is found more towards the roof than the footwall. A small branch or pipe of crystallised quartz was seen near the outcrop.

Key and Parry's pipe is very large, and is composed in the main of quartz, with a considerable amount, however, of interstitial granite and pegmatite and secondary mica representing the replacement of felspar in the granite.

Murphy's Pipe consists of a number of quartz veins and patches connected by granite and granular silica and containing felspars replaced by secondary mica and silica.

Timbarra.—Certain gold pipes occur to the east of Tenterfield in granites which have an appearance similar to the tin granites of New England. These pipes, as observed by the writer twelve years ago, were worked for their gold contents, and, in at least several instances, they have a core of secondary mica which passes gradually outwards into unaltered sandy granite.

Rocky River Pipes.—Certain pipes, such as those on Goodwin's Block, are of white quartz, but the remainder appear to be of granite material containing quartz in masses and flat lenses, the whole passing into unaltered granite within short distances of the pipe walls.

Wilson's Downfall, Maryland.—The pipes in this district appear to consist of pegmatite, in which large grey felspar crystals may occur individually or in clusters within a paste of bluish quartz. In places the deposits have the appearance of a very siliceous granite. Secondary mica may occur in the felspars of these pipes, but if so they were not noted by the writer.

Whipstick.—In this locality, about 35 miles south of Bega, the pipes occur in groups. These appear to have branched as they approached the old granite roof, now removed in great measure. Some of the pipes appear to

consist of very sandy granite, others of mica, garnet, and granite, others of granite with much garnet. One appears to be composed of garnet with granite walls; another is a garnet granite with a mica collar, while another is of white massive quartz, possessing a narrow and outer casing of garnet passing into the granite of the country rock. The quartz pipe appears to be homogeneous if examined at and near the core, and it is only upon an examination of its outer zone that the suggestion arises that the granite had first been altered to garnet, in part, and finally to massive quartz at the core.

So also if the "granite" pipes be examined, it will be found that garnet has been developed abundantly throughout their mass. The distribution, however, of the garnet is irregular. In one place a pipe may contain only numerous small kernels and masses of the garnet, while in another the garnet may be in masses many tons in weight. Similarly the secondary mica has a very capricious distribution.

Summing up this information, it may be inferred that the quartz pipes themselves, as a rule, exhibit a peculiar and interrupted dip which appears to be a modification of the "step-and-tread" form; that the pipes have no well-defined walls; that veins or flat lenses of material carrying molybdenite accompany the pipes in certain cases; that no large intersecting joints are visible from whose intersection the pipes may be supposed to have grown by replacement of the granite; that the quartz of the pipes is not homogeneous, but, in many cases, shows a change outwards from a cavernous core through massive, brittle, or tight granular silica to granite country.

A consideration of the associated pipes which are not composed wholly of quartz reveals the existence also of deposits whose formation appears to have been due to the same group of agencies as that which gave rise to the quartz members. These associated deposits, which are intimately related to the quartz pipes, represent siliceous types of granitic material. These are named from the predominating mineral or minerals present, whether such be secondary mica, garnet, mica-garnet, or pegmatite.

All of these, except a few doubtful forms in the Wilson's Downfall and Bolivia districts, exhibit passages from the mineral association of the ore deposits themselves to that of the granite country.

From these field notes it would appear permissible to infer that the quartz pipes originated in the replacement of granite. It is possible that vapours containing silica, sulphur, molybdenum, bismuth, and other materials, arose along zones and planes of weakness and acted strongly upon the granites in the neighbourhood of such zones, especially at places where two zones intersected each other. The earlier action appears to have brought about clouding of the felspars, with the development therein later of secondary mica and a final replacement by quartz, by molybdenite and bismuth.

Localities containing quartz pipes.—Kingsgate (mainly quartz pipes), Rocky River (less than half the pipes are quartz), Whipstick (only one known to be quartz).

2. Pegmatite Pipes.—These have been described already. Localities, Maryland (Wilson's Downfall district), Bolivia (Cooper's Old Pipe), Deepwater (in part), Deepwater River (Kiernan's Pipe), Bald Nob (Murphy's Pipe.)

Dr. Pirsson has given a simple statement concerning the opinions generally accepted by geologists as to the origin of the pegmatites. An extract from his book is here inserted.*

* Rocks and Rock-forming Minerals. 1913, pp. 178–180.

"When a body of igneous magma, such as will form a stock or batholith, comes to rest in place it will commence to cool. This will naturally take place first in the upper and outer portions, and here will begin the solidifying of the mass by crystallisation. As it becomes solid it breaks up into jointed masses by contraction. The weight of these masses, aided by the rock pressures from above upon the still liquid material below, tends to force the latter upward into the fissures in the solidified part and into those of the surrounding rocks and produce dykes. . . . . But as the process of crystallisation goes on, the volatile substances in the magma, and especially water in great quantities, beyond what is retained by such minerals as use them in their chemical composition, will be excluded, and more and more as the gases accumulate they must find their way outward. Thus they will tend to force their way upward along the fissures in the solidified parts above and at their sides. These cracks will therefore become channel ways, not only for the still unconsolidated magma as mentioned above (whether differentiated or not), but also for the vapours which will collect in them and in those of the immediately surrounding rock mantle under pressures, which must often be enormous, until eventually they escape. It is evident from this that the ascending magmas in the fissures will at various places become supercharged with these vapours far beyond what obtains in the normal rock. Now, both on experimental grounds and what is observed in nature, it may be regarded as almost certain that no sharp line can be drawn between igneous fusions of silicates (molten silicate magmas), containing water under pressure and hot water solutions. It appears that under pressure water will mix in all proportions with magma, so that at one end are molten fusions, at the other hot solutions.

"At 360 degrees water reaches its critical point—that is, heated to this degree, or above, its vapour cannot be turned back into liquid by mere pressure, however great this may be. At this temperature its expansive force is almost 3,000 lb. to the square inch, which would require a vertical height of about 2,500 feet of granite rock to contain it. Above this temperature sufficient pressures cause it to contract rapidly, and it may even occupy less volume than it would in the liquid state. The temperatures obtaining in molten rock magmas are far above the critical temperature of water, and it must therefore be in the gaseous condition, though under the enormous pressures obtaining under thousands of feet, or even several miles vertical of overlying rock, it may well be much denser than water at the surface. Although it has not yet been shown, so far as the writer knows, that water in this state holds substances in solution just as though it were a liquid, we can well imagine that at high temperatures, aided by the fluorine and other active substances so commonly with it, its solvent action must be enormously increased, especially its ability to dissolve silica.

"Under such conditions it is easy to see that the minerals would crystallise quite differently from those in the normal rock. In some places the magma would be in excess, and the results would more nearly approximate those obtaining in the main rock. With diminished water the dike might pass into an ordinary aplite or felsite phase. With increased amounts in another place it might pass from the state of a magma into an aqueous solution, and here would be favourable conditions for crystallisation on a large scale, for growth outward from the walls and for the segregation of the rarer elements. Finally passing onward, the

solution phase might become more pronounced, only silica would be carried and the dike turn into a quartz vein. Thus, as the degree of differentiation of the magma and the proportion of magma to water vary, we can see how dikes of ordinary rock, of variable pegmatites and quartz veins may be formed, which show in places very clearly their genetic relationships. Also the slow cooling that would occur in great masses of heated rock enclosing the fissure would be favourable for the production of large crystals."

3. Granite Pipes.—The main points of geological interest in connection with pipes of this type have been included under the heading "Quartz" pipes. *Localities*—Bolivia and Deepwater Pipes, Rocky River (in the main), Whipstick (nearly all granite), Kingsgate (several).

All of these types show intimate relations with the pegmatite pipes, and in places are scarcely distinguishable from them.

4. "Mica-Garnet" Pipes.—The "Gold" pipe of Whipstick was characterised by the presence of abundant mica to a depth of 80 feet, at which depth it appeared to pass into a garnet-granite pipe. This mica appeared to be secondary; it was soft in bunches and nests through the granite so as to give the appearance in places of great masses of secondary mica. The oxidation of the associated garnet caused the outcrop to have the appearance in part of a manganese gossan.

5. "Garnet" Pipes.—Whipstick possesses a garnet pipe which has been found 210 feet below the No. 1 Tunnel. All of the granite pipes of this locality contain a considerable amount of this mineral.

(*b*) *Pegmatite and aplitic segregations.*—These are exceedingly common throughout eastern New South Wales, in the plateau province. They may be small or large in extent.

They are accompaniments of the tin and wolfram granites, rather than of the true molybdenite types, and their general form as large octopus shapes, as blunt tongues, long dykes, "bungs," or as large or small secretions of irregular form, has been discussed already under the head of the granites. In proportion as these segregations or intrusions are drusy, cavernous, irregular in texture, and pegmatitic to graphic-granitic in appearance, are they liable to contain flakes of molybdenite as an accessory constituent. The molybdenite appears to be part and parcel of such granite intrusions or segregations, and, in some of the larger occurrences, the amount of molybdenite contained must be enormous. The amount of concentration of such molybdenite, however, is rarely sufficient to justify mining and treatment expenses. This subject, however, is considered under the heading "Hints to Prospectors."

Soft mica, of secondary appearance, is a common associate in certain localities.

Localities.—Booroolong, 25 to 30 miles north-west of Armidale. The area containing the aplitic and pegmatitic segregations here is large, and one or two of the outcrops are promising in appearance, and are worthy of further prospecting. Bald Nob (15 miles east of Glen Innes), Wilson's Downfall, Moonbi, Tarana, Yetholme, Guy Fawkes, Tantawanglo Mountain (near Cathcart), Laura Creek (18 miles from Bundarra), and other places.

(*c*) *Pegmatite veins.*—True pegmatite veins are rare in New South Wales. One occurs on the high plateau near the Main Divide, east of Deepwater. The country consists of a coarse siliceous, or wolfram-granite. The pegmatite vein has been traced for a distance of a few chains, and it merges at each

end into a true quartz vein of slight width only. The molybdenite content occurs as a constituent of a coarse pegmatite, forming the central portion of the vein, the pegmatite consisting of very coarse crystalline pink felspar, with very coarse quartz of a bluish colour (Fig. 8). Its age appears to be that of the other molybdenite deposits of New England.

(*d*) *True quartz veins containing molybdenite.*

1. In large patches of greisen, forming marginal developments to coarse sandy granite types.

A good example of this occurs at Rummery's Claim (Fig. 9), about 12 miles east of Deepwater. In this locality several quartz veins have cut across a great mass of greisen. The original quartz vein appears to have been very small, the vein growing in size by the replacement of the greisen by quartz. The principal mineral present is wolfram, the molybdenite and bismuth being subordinate altogether in importance.

Elsmore.—In this category the Elsmore tin veins may be placed. They occur as quartz veins containing flakes of molybdenite in places. The veine are in greisen, all being associated with a very silicecus granite.

2. *In fine-grained tin granites.*—Molybdenite in quartz veins in these rocks is not a common occurrence, but in several localities containing such rock types there may be found narrow quartz veins arranged marginally to the enclosing granite of fine texture. The ground is hard, the veins narrow or wide, and the molybdenite content not large so far as known exposures are concerned.

Localities.—Haystack Mountain at margin of the tin-wolfram granite. The granite is intrusive into quartz porphyry, and forms a marked topographic feature. The veins are narrow. *Oban.*—30 miles south-south-east of Glen Innes. Very narrow veins of quartz in tin-granite near its intrusive contact with basic granite, the quartz veins being arranged at right angles to the general trend of the intrusive contact. The tin granite here makes a rugged topography dominating the general level of the basic-granite surface.

Moonbi.—Small quartz veins in aplitic or pegmatitic granite near its intrusive contact with sphene-hornblendic granite. Some of these quartz veins occur in Bett's Claim, also on Russ and Edward's Claims.

Black Range, Bega.—Scott's Reef and Finucane's Reef are *large and well defined* veins of quartz in a coarse and fine-textured granite of very siliceous nature. This granite appears to be a marginal development along the roof of a basin type of granite, which is widely-spread throughout the Bega district. Its age appears to be closing Devonian. There is actually a considerable amount of molybdenite in these lodes, but it is not known as yet definitely whether the percentage is high enough to repay mining and treatment expenses.

Wilson's Downfall.—In the vicinity of the Sugarloaf Mountain. The tin-granites contain narrow quartz veins, in which wolfram tin and molybdenite all occur. The granite alongside has been altered to greisen for varying distances.

3. Veins in coarse basic granite near its contact with aplite or other very siliceous granite of fine texture.

These veins are well defined; they possess excellent foot and hanging walls. The veins may be narrow or of considerable width. They may or may not be attended with dykes, and they may contain minerals other than molybdenite and iron pyrites. In each case, however, their intimate association with neighbouring aplites is evident.

Localities.—Moonbi.—The main veins of this type at Moonbi, so far as at present known, occur within Russ and Edwards' Claims. The veins are flat lenses varying in width from 2 to 20 inches. The extreme length, as proved for an individual vein, is perhaps 10 or 12 chains. The strike is about N. 80° E., and the dip is to the north. In one case an aplite dyke follows the vein at a short distance away, in another case a lamprophyre basic dyke occurs with the vein. Scheelite occurs with the molybdenite in one vein, and copper pyrites occurs in the other in association with the molybdenite.

Attunga.—The molybdenite deposits of this district have not been examined by the writer, but from a personal knowledge of the granite in the paddock containing the deposits, and from other information received, it would appear that the molybdenite occurs in small quartz veins contained in the marginal portion of a coarse and basic granitoid rock with abundant hornblende, biotite and sphene.

Black Range, Bega.—The Queensgate, or Jackson's Reef, is a well-defined lode of massive white quartz in a basic granite near and at its contact with intruded Devonian claystone, sandstone, and conglomerate. On the same mineral lease an abundance of aplite or very siliceous granite occurs. The reef has a strike almost east and west, its underlie is regular and slight, its walls are pronounced, it has been proved over a length of 200 yards, and its width varies from 12 to 36 inches. The molybdenite is of the paint variety, being very thin and fine, and scattered throughout the joints in the stone, and this description also fits the occurrence of molybdenite in the neighbouring large quartz reefs, known as Scott's and Finucane's Lodes. The three appear to be intimately related.

4. Narrow veins in coarse and fine granite near sediments.

This type includes the Warrell Creek molybdenite deposits (Pl. XIX and Fig. 20).

Here, according to Mr. J. E. Carne, Government Geologist, and Mr. J. R. Godfrey, Government Inspector of Mines, the veins are very narrow and occur in parallel, but discontinuous, series. The molybdenite occurs in massive crystals (Pl. XIX), and magnificent specimens from these reefs are on exhibition at the Mining Museum. Were the veins somewhat wider, they would be well developed. Their narrowness, discontinuity in length, and patchiness, however, have hampered their proper development up till the present.

5. Network of quartz veins in extremely siliceous quartz and felspar porphyries not visibly connected with granites.

At Glen Eden, about 12 miles north of Glen Innes, alongside the main northern road, a peculiar zone of alteration occurs. In this locality a mass of quartz and felspar porphyry, extremely siliceous in nature, has been traversed in a general north-north-west direction by a zone of interlacing quartz veins. The zone exceeds 1,000 yards in length, as proved by prospecting operations, and it exceeds 400 yards in width. The individual quartz veins are not large and are discontinuous. The general trend is northerly, but cross veins are extremely common. The porphyry between the veins exhibits all variations in alteration from a clouding of the felspars and the matrix to a complete replacement to greisen or quartz. Quartz with tin, wolfram, and molybdenite, crystals appears to be the final stage of replacement.

The remarkable fact in connection with this molybdenite deposit is the absence of visible granite of siliceous nature in the immediate vicinity. Siliceous granites, however, carrying tin and molybdenite deposits occur

about 2 miles to the east, or north-east, towards Bald Nob, and it is probable that the occurrence under consideration has been due to the action of vapours, or solutions, or both, expelled from the roof of an intrusive granite lying at a slight depth below the surface at Glen Eden, and intimately related to the Bald Nob granite lying to the north-east.

(*e*) *Contact Deposits.*—These are rare in New South Wales, the only authentic example of such types having been recorded from Yetholme and Gemalla, in the Bathurst district, and possibly from Red Rock in the Drake district. It may be found hereafter, however, that the peculiar contact deposits at Duckmaloi River and Diamond Hill, in the same district, contain molybdenite, and in such case, this might be an occurrence similar to the Yetholme and Gemalla type.

Illustrations of the contact deposits at Yetholme will be found on page 176.

A large mass of rock, mainly of basic granite types, appears to have had marginal developments of, or to have been intruded by, pegmatitic and siliceous granites both fine and coarse in texture. The age of the intrusions appears to have been post-Devonian but pre-Permo-Carboniferous. In the neighbourhood of Yetholme and Gemalla, the siliceous granites have intruded limestones, claystones, sandstones, and volcanic-ash beds. To the immediate north the siliceous granite is cavernous and porphyritic to fine in texture, and it contains scattered molybdenite flakes as an accessory constituent. Still further north the granite is coarse and more basic and contains small quartz veins with flakes of molybdenite, as in Donaldson's paddock. Under Mount Tennyson, or the Yetholme molybdenite field proper, the granite is coarse and siliceous, and it has a marginal development of considerable width, of a granite varying in texture and composition. In places it has a siliceous pegmatitic appearance; in others it appears as an aplite; in other places this aplite merges into a granite of fine texture containing small basic minerals. The latter is distinctly a marginal phase.

From the granite margin for a distance not exceeding a mile, as a maximum, from the granite, a belt of garnet-rock occurs in the intruded rocks. The belt is of considerable length, having been traced along the granite margin and between the intruded members for a distance of several miles with breaks. It is relatively thin, and has not been observed to possess a thickness exceeding 39 feet. Claystone and discontinuous lenses of limestone, altered to marble as a rule, form the beds immediately underlying the garnet-rock, while quartz porphyry, claystone, fine-grained volcanic ash, and sandstone, form the bulk of the rock immediately overlying the garnet-rock.

The garnet rock does not appear to have been developed between any two particular layers or beds, inasmuch as in the more southern portion of the field no limestones occur *in situ*, and beds there are found overlying the garnet zone which in the northern portion of the field have been seen only under the garnet zone.

The garnet zone contains the molybdenite flakes. This ore zone or belt also contains amphiboles, epidote, calcite, and innumerable eyes, blebs, streaks, and small patches, of quartz. Nearer the granite this garnet zone is separated from the sediments proper by transition zones of considerable thickness, but farther from the granite this transition zone is much thinner In the north this consists in part of bases of limestone *in situ*, changed to marble, and in which much garnet, as kernels and networks, has been developed in part. In the south it consists of claystone or volcanic ash, or quartz-porphyry in which zones of wollastonite kernels have been developed, and in which patches of amphibole and garnet have also been developed.

These zones are narrow, and are parallel both to the original planes of bedding and to the plane in which the main garnet-molybdenite-amphibole-quartz zone has been developed.

These wollastonite structures are remarkable in that they occur commonly as spheroids inside the bedded claystone or volcanic ash beds without apparent direct connection with any limestone bed. Moreover, many of the wollastonite spheroids have nuclei of granular marble (Fig. 37). This feature is especially noticeable in the southern portion of the Mount Tennyson Field, and at Borchardt's Claim, 3 miles from Tarana. In the latter claim a granite sill has intruded masses of sediment of fine texture, apparently claystone or fine-textured volcanic ash. These thinly-bedded rocks (Figs. 30 and 31) have been altered to quartzite, but within their mass there has been a capricious development of wollastonite and garnet nodules on each side of the granite sill (Fig. 44). No limestone was seen *in situ*, and no knowledge is had of such in the vicinity, nevertheless large blocks of marble occur scattered throughout the altered sediments. Wollastonite spheroids with marble kernels also occur in the altered mass.

This remarkable feature also occurs noticeably in the southern portion of the Mount Tennyson Field, where again, no limestones occur *in situ*.

The geological examination of this locality has been only of the nature of reconnaissance work, no detailed petrographical and chemical studies having been undertaken, nevertheless it would appear that the neighbouring granites had a marginal development, in this region, of siliceous aplites, pegmatites and allied granitic types, and that vapours containing much silica, iron, molybdenite, and other elements, penetrated a weak zone of limestone, calcareous volcanic ash, sandstone, quartz-porphyry, and other rock types, and interacted on these so as to cause segregations along the zone in the first place of limestone and amphibole, and that by the introduction of more silica these were gradually replaced by wollastonite, garnet, and various amphibole rocks, the final stage being the development of brown and green garnet, massive and crystallised, green amphibole, and quartz with molybdenite. The prevailing tendency in the central zone of circulation was to form pure silica, and in proportion to the development of this mineral in streaks and small lenses or patches, so was there a tendency for the formation of molybdenite.

This mineral occurs in small flakes and as paint molybdenite in the garnet zone, being rarely found in the wollastonite or transition zone. This conclusion is in general accord with the earlier and joint report* by Messrs. J. E. Carne and E. C. Andrews.

The accompanying extracts from reports by L. C. Ball and C. W. Drysdale on molybdenite in contact deposits in Queensland and Canada respectively, are interesting in the light of the foregoing notes on the Yetholme contact phenomena.

The first extract is from a memorandum by L. C. Ball† on a set of specimens submitted by Mr. Inspector M. Russell from a molybdenite deposit at Boomarra, Cloncurry District, Queensland.

" The rock samples forwarded by Mr. Russell with his report on the occurrence are crystalline calcareous metamorphics, such as are found occasionally on our mineral fields along granite contacts. Calcite is abundant, with much

* Annual Report, 1915, pp. 175–177.
† *Queensland Govt. Mining Journal*, XVI, 1915, p. 300.

fibrous green hornblende in a matrix of pinkish felspar. One of the specimens is very siliceous and contains a few minute spangles of molybdenite. The other exhibits thin stringers of chalcopyrite.

"The specimen . . . . from the limestone crop, which Mr. Russell found to contain molybdenite *in situ*, consists of a coarse crystalline aggregate of granular calcite, with a few crystals of quartz and numerous pencils of a dark green silicate believed to be actinolite. The occurrence of molybdenite in a matrix of this description is probably unique."

The second extract is from a report by Chas. W. Drysdale* on a deposit at Lost Creek, Nelson Mining Division, B.C. In describing the occurrence of the "Molly" deposit he states that it "is associated with the upper border of a large intrusive mass or batholith of granitic rocks, which have been laid bare by erosion. . . . . The chilled border of the stock forms a hard shell averaging about six feet in thickness, and composed of a fine-grained aplitic variety of granite dotted through with a few molybdenite grains." (p. 252.)

* Geology of the Molly Molybdenite Mine." Trans. Canad. Min. Inst., vol. XVIII, 1915, pp. 247-255.

X.—NOTES ON THE PROSPECTING AND MINING OF MOLYBDENITE DEPOSITS.

Molybdenite mining is only in the pioneer stage, and it thus appears advisable to supply a few notes on the prospecting of deposits containing the mineral under discussion. The numerous "pipes," veins, "bungs," aplitic and pegmatitic masses have been found through the untiring efforts of that capable and resourceful band of men known as prospectors, who, by their courage and their indifference to discomforts, have done so much to open up the immense mineral possibilities of Australia. But whereas the prospector may have a wide knowledge of local conditions, as at Kingsgate or Whipstick, it may be that he has little or no knowledge of local conditions in places such as Yetholme, Bega, Moonbi, Deepwater, or the Rocky River.

The accompanying brief notes may enable the prospector, or miner, of one district to appreciate the special difficulties which he may have to face if he is determined to try molybdenite mining in districts other than his own.

In New England, as in New South Wales and Queensland generally, molybdenite deposits occur either at, or near, the contact of certain granites and the rock which has been intruded by these granites. The deposits usually occur also within the intrusive granite.

Not all the granitic and granitoid rocks of New South Wales contain molybdenite deposits. The so-called "Blue Granite" of northern New England, for example, which is very common about Tent Hill, Deepwater, Bolivia, Dundee, Wallangarra, and Tenterfield, is not known to contain the mineral under consideration. Neither does that great mass of granite, magnificently porphyritic with very large pink felspars, and common at Tenterfield, Bungulla, Undercliffe, Wallangarra, Wilson's Downfall Creek, the Rocky River, Drake, and along the Tenterfield-Drake Road, contain molybdenite deposits. Nor do the dark granites of Uralla, Glen Innes, Hillgrove, Bendemeer, Glen Elgin, Bathurst, Tallong, Braidwood, Gulgong, Grenfell, Young, and many other places, contain molybdenite. It is rare, indeed, to find granites, such as those here enumerated, containing molybdenite at all. Two exceptions occur in the cases of the Moonbi and Bega deposits, where true quartz veins containing molybdenite occur in dark granites. In each case, however, the veins are intimately related to masses of very sandy granite, fine in texture, which have intruded the dark granites in the vicinity of the quartz veins.

Molybdenite Granites.—It may be of interest to the prospector to know that molybdenite occurs in almost every sandy type of granite in New South Wales. Nevertheless, there are certain sandy granites in the State which are much more intimately associated than others with molybdenite deposits of importance. These are the granites which contain the pipes of Bolivia, Deepwater, Kingsgate, Whipstick, and some other places. They are coarse and granular in texture; they have intruded the associated rocks in broad gentle curves; their junctions with the neighbouring rocks are distinct and can be traced with the greatest ease; the country is of open forest, rather than of scrubby nature, and, as a rule, they occupy the lower, rather than the highest, points of any locality. In these granites the molybdenite deposits occur usually as "pipes."

Molybdenite occurs also in the tin and the wolfram granites, but within New South Wales it is rare, as in the case of the Rocky River deposits, that the molybdenite occurrences are of importance in such granites. The tin

and the wolfram granites are much more sandy than the true molybdenite types; they may be coarse in texture, and porphyritic in nature; their junctions may, or may not, be broadly curved and distinct; they occupy the highest points of the landscape, with the exception of the quartz-felspar porphyries; they are extremely scrubby in nature, very rarely forming open-forest country; and they are always associated with marginal patches of abundant soft mica, and with small or large irregular knots and masses of fine-grained sandy granite or aplite, from which numerous tongues and veins of pegmatite and aplite extend in all directions. The molybdenite occurs in these either as small veins, or as flakes scattered irregularly and sparsely throughout acres of the fine-grained sandy types. The wolfram-granite of the Rocky River is an exception, the molybdenite occurring with the wolfram in "pipes" near the granite and porphyry junction, and in pegmatite mantles to the wolfram granite.

General Occurrence of the Molybdenite.—The molybdenite may occur as "pipes" of quartz, of pegmatite, or of very siliceous granite, dotted irregularly round the margin of the containing granite, and dipping, as a rule, in a direction parallel to the general plane of contact of the granite and the associated rock masses. The molybdenite may occur also in true veins in granites near their intrusive junctions with other rocks; it may occur as contact deposits in association with sandy granites, the contact deposits themselves, as at Yetholme, having the appearance of seams varying from 2 to 35 feet in thickness; or the molybdenite may occur as flakes irregularly and capriciously scattered throughout a drusy mass of quartz and felspar.

Throughout the whole of the great plateau district of New South Wales these sandy granites, with their marginal developments of pegmatite, cavernous aplite, dykes of aplite and graphic granite, and quartz deposits, are quite common. They are especially common in the central and rugged eastern portion of New England as near Stanthorpe, at Tenterfield, Bolivia, Deepwater, Guy Fawkes, the Timbarra River, Booroolong, Moonbi, and other places. The areas drained by the Hunter and Hawkesbury Rivers appear to be lacking in outcrops of these sandy granites, but farther south and west they occur in the Parkes, Pulletop, Bathurst, Ardlethan, Holbrook, Bega, Wyndham, and Monaro areas.

Detailed descriptions of the tin-bearing localities in this State have been supplied by Mr. J. E. Carne.*

In these great tin-bearing districts enumerated by Mr. Carne, molybdenite occurs only in rare patches, and there only as a mineral curiosity; no deposits of commercial importance having been recorded therefrom. Wolfram occurs more or less plentifully in the great tin-bearing districts, but in the important Mole Tableland aera, the main deposits of the wolfram are arranged at and near the contact of a large slate and conglomerate island in what appears to be a sea of granite, whereas the principal tin deposits are arranged peripherally with respect to the main mass of the granite itself. These tin and wolfram granites stand high above the surrounding country, but the molybdenite granites generally form the lower portions of the plateau areas.

Detailed descriptions of the wolfram deposits of the State are to be found in the Mineral Resources Series of the Department of Mines.†

* J. E. Carne. The Tin-Mining Industry of New South Wales. Mineral Resources, No. 14. 1911.

† J. E. Carne. The Tungsten-Mining Industry in New South Wales. Mineral Resources, No. 15. 1911.

(*a*) *Prospecting of "Pipes."*—Pipes may be of quartz, pegmatite, of felspar crystals set in a matrix of quartz, of granite containing abundant mica and garnet, or of a very siliceous granite.

The outcrops of these pipes vary very much in appearance according as the mineral composition of the outcrop varies. Thus the large quartz pipes of Kingsgate outcrop as white quartz, the garnet-bearing pipes of Whipstick may outcrop either as dark masses like manganese gossans, or as masses of mica containing manganese stains. The granite and pegmatite pipes of Deepwater, the Rocky River, and Kingsgate have inconspicuous outcrops which are recognised only with difficulty.

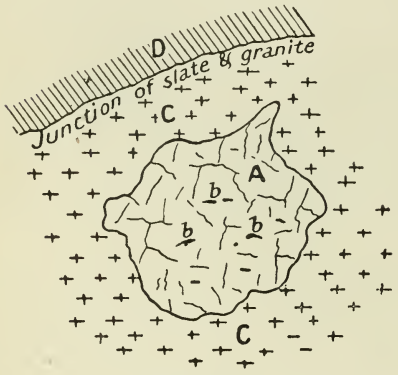


Fig. 2 (*a*).
Plan of Pipe.

Quartz Pipes.—All patches of quartz which are more or less circular or oval in plan, and which are found near the margins of sandy granites, should be examined carefully for flakes of molybdenite or for traces of the yellow or yellowish-white powder known as molybdic ochre, and which results from the action of the weather on the bright, shining plates and flakes of molybdenite. The pipes also may be exposed at the surface only as loose blocks of quartz overlying the main pipe itself, or the scattered quartz pieces may have been shed downhill from a pipe. It may be that the pipe appears to contain neither molybdenite nor bismuth at the surface, but cavities may exist in the mass of quartz suggesting that molybdenite has been removed by solution from the upper portion of the pipe. In such case the prospector would be well advised to remove the portion near the surface, and a search might be made for signs of molybdenite or molybdic ochre at a depth of a few feet from the surface. In one of the large quartz pipes at Kingsgate the molybdenite and bismuth were almost absent from the outcrop, and the deposit was abandoned. At a later stage a race, excavated for sluicing purposes, exposed the pipe material at a depth of 20 feet, at which depth molybdenite and bismuth were abundant.

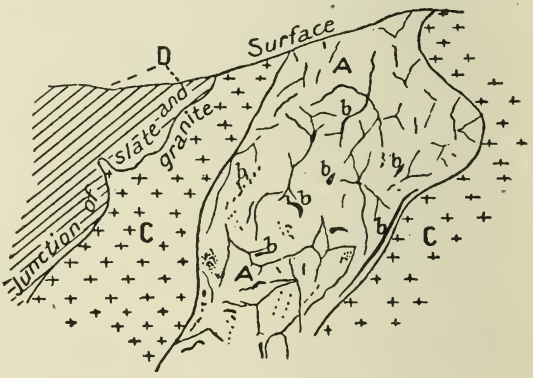


Fig. 2 (*b*).
Section of pipe showing possible appearance of (*a*) when quartz is followed down.
A = Quartz (pipe). *b* = Masses of molybdenite.
C = Coarse or fine sandy granite.
D = Claystone or other associated rock.

Nevertheless, the prospector need not expect to sink as much as 20 feet within the deposit in most cases before obtaining indications as to the advisability of proceeding with the prospecting operations. If the deposit belongs to what is known as the payable class, the molybdenite should be freely visible in the quartz, and as a rule, this should be indicated within a few feet of the surface.

Specks or flakes of molybdenite scattered here and there throughout the quartz may encourage a prospector to continue the search, but stone of such quality would be valueless as ore. The prospector, therefore, must be prepared for disappointments even on the supposition that he has found a pipe, for many pipes do not contain molybdenite, and even of those which do contain this mineral, only a few may be expected to contain it in quantities sufficient to repay the expenses of mining, treatment, and realisation.

Not only so, but the pipe cannot be expected to possess a uniform molybdenite content. All pipes contain so-called barren stretches, that is, portions —large or small—throughout which the molybdenite content is insufficient to return working expenses connected therewith. The famous "Old 45," or Sachs' Pipe of Kingsgate, was found to contain a blank of great length immediately below the great chamber from which the large tonnage of rich molybdenite ore had been won during the period 1902–1908.

But supposing for the time being that the pipe which is being prospected should contain molybdenite near the surface in quantities such as to justify the continuation of sinking operations, the question then arises, "How is the pipe to be prospected profitably with the least outlay of capital?" Is it not possible, or proper, for instance, to sink a vertical shaft at a certain distance and in a given direction from the outcrop so as to intersect the pipe at a given depth on the undeveloped deposit, thus proving the existence of the ore body at the depth estimated and at the same time reducing the mining expenses? For example, if the deposit should underlie to the west at what is known as "half-the-angle" for a depth of 60 feet, would it not be proper to sink a vertical shaft at a distance of 200 feet to the west, and expect to prove the pipe at a vertical depth of 200 feet? This method of laying-out work in advance implies the uniformity of underlie for the pipe both in direction and amount to a vertical depth of 200 feet, or a depth of about 283 feet as measured along the underlie. But such a conclusion is not at all justified by the experience gained in pipe-mining in New South Wales, as may be seen at a glance at the figures accompanying the descriptions of the Kingsgate and Whipstick deposits in the main body of the report. In brief, the pipes of Kingsgate, Deepwater, Wunglebung, Whipstick, and North Queensland, vary both in inclination and direction in a surprising manner.

The only satisfactory manner, therefore, to prospect these peculiar deposits is to follow them throughout their various contortions and not to leave them on any consideration. Great care also is necessary in following the pipe downwards. As a rule the pipes vary considerably in size from point to point; here a pipe may have a width possibly of 20 or 30 feet, whereas, a few yards farther along, it may have shrunken to a width not exceeding 12 or 18 inches. Immediately below the long and wide chamber excavated in the "Old 45" at Kingsgate, and from which many tons of molybdenite were won, the pipe appeared to have contracted to a diameter of about 18 inches, and the prospectors were years searching for the continuation of the pipe beyond and below the chamber.

Not only so, but the walls of the pipes are irregular in form, and tongues of quartz, with or without mica, and known as branches and "droppers," may extend into the surrounding granite. Or, again, the pipe may lie in the general plane of a powerful joint, with patches of quartz containing molybdenite extending along the joint plane for distances varying beyond the limits proper of the pipe, such as appears to be the case with the No. 2 Pipe at Bow Creek, Deepwater.

In all these cases the greatest care and skill is needed so as not to lose the main pipe itself.

On the other hand, various guides or signposts, as it were, are to be found in the majority of pipes. Thus in many pipes a bend is indicated by the peculiarity of the arrangement and appearance of the quartz and molybdenite in the corner immediately above the bend; in others, molybdenite (or wolfram) projections above the main pipe indicate a probable turn in the pipe immediately beyond; while in others a seam or band of molybdenite generally indicates the main trend of the pipe.

It will be evident to a miner that the cost of working these irregular and tortuous bodies must be considerable, since it is almost impossible to forecast where the pipe may have opened out or where it may have shrunken almost to a thread, or where its dip may have changed either in direction or amount.

At the surface the cost of mining is almost negligible, but as soon as the prospector has sunk to depths greater than 50 feet in a pipe of hard quartz and, say, 5 feet in diameter, the price of mining and hoisting to the surface may be set down at £2 10s. to £3 a ton of ore raised.

This introduces the consideration as to the average amount of molybdenite necessary to enable a deposit of this type to be worked at a profit. Mere specks or flakes of the mineral occurring here and there in the quartz may be interesting from a scientific point of view, but for the purpose of profitable mining the mineral must be abundantly distributed throughout the quartz. It is probable that no ore is so likely to deceive the novice as molybdenite, both because of its bright flashing appearance contrasted with the white or grey matrix and its occurrence generally in very thin plates or leaves. The novice in molybdenite mining, however skilled he may be in copper, lead, zinc, tin, wolfram, and gold ores, in spite of himself, is led to consider the broad opaque flake of the mineral as possessing a thickness comparable with its width or length, as in the case of copper, lead, zinc, and other ore fragments. At a few mines, such as at Kingsgate and Bow Creek, the crystals of molybdenite are generally thick, and thus an estimate, somewhat reliable, may be made of the percentage of molybdenite present even by inspection; but in most mines the flakes of molybdenite are so thin that a fair estimate by inspection of the quality of the ore could be made only by experienced prospectors and miners of molybdenite. In the case of the bismuth which may be present, the untrained but careful prospector will under-estimate, rather than over-estimate, the percentage, but in the case of the molybdenite which may be present it is almost certain that the same man would estimate the molybdenite content at three or four times its actual amount. One per cent. by weight of molybdenite is about 22 pounds avoirdupois to the ton, and an amount such as this distributed as very thin and flashing plates would make quite a good showing in white quartz.

With regard to the question as to what percentage of molybdenite should be present in a deposit such as that under consideration to enable it to be

worked at a profit, it may be stated that it is difficult to supply a satisfactory answer, owing to the varying conditions under which each deposit occurs as a rule. Thus a pipe may occur in mountainous country at a distance of 50 miles from the railway by execrable road or track, the railway depôt may be 500 miles from a port; the mine may be very wet, and labour at such a place may be inefficient, especially if only a couple of unskilled prospectors are employed.

Assume, however, that the pipe is about 5 feet in diameter, that it occurs in mountainous country at a distance of 320 miles from Sydney, namely, 300 by rail and 20 by road from the mine to the railway, the last two miles being over mountainous and rough track; that the molybdenite occurs in large and small but thin flakes; that it occurs in massive quartz to the extent of 1 per cent. in one example and 2 per cent. in another example by weight of the ore, and that the material can be picked by hand to 4 or 5 per cent. molybdenite for 5s. a crude ton, and that 80 per cent. of the ore is saved by this method.

The ore thus dressed may be despatched to the port direct for treatment, or it may be treated locally in a mill.

Firstly.—Ore dressed to 5 per cent. molybdenite and sold to ore-buyers in Sydney.

Ore without impurities and containing about 5 per cent. molybdenite was sold in Sydney during 1915 and the early part of 1916 at a rate varying from £2 10s. to £3 a unit, approximately. It is improbable that sellers can expect a price exceeding £2 10s. a unit now for this class of ore. Ore containing 87 per cent. and upwards of molybdenite is worth about £4 13s. 4d. a unit at the present time delivered in Sydney. Each ton of 5 per cent. concentrate thus may be considered to be worth £10 to £12 10s. a ton, say, in Sydney, or at the port to which it may be sent.

If 80 per cent. of the molybdenite be recovered, then $6\frac{1}{4}$ tons of crude ore must be picked in the case of the 1 per cent., and $3\frac{1}{8}$ tons in the case of the 2 per cent. material to produce 1 ton of concentrate containing 5 per cent. molybdenite.

The expenses are approximately :—

	£	s.	d.
Mining on $6\frac{1}{4}$ tons, at £2 10s. a ton, say	15	12	6
Breaking and picking $6\frac{1}{4}$ tons of ore from 1 to 5 per cent. MoS_2, at 5s. ...	1	11	3
Freight to rail on 1 ton of concentrate, say	2	0	0
Freight to port by rail—			
240 miles at $\frac{1}{2}$d., and 60 miles at $\frac{1}{4}$d.	0	11	3
Bags and bagging (bags used three times, say)...	0	7	0
Freight, sampling, assay, &c., in Sydney, on 1 ton of concentrate, say	0	10	0
	£20	12	0

The apparent loss on each ton of concentrate is therefore considerable.

In the case of ore containing 2 per cent. molybdenite, the producer may be expected to receive £12 10s. a ton for 5 per cent. molybdenite concentrate.

Approximate expenses :—

	£	s.	d.
Mining on $3\frac{1}{8}$ tons, at £2 10s., say	7	16	3
Breaking and picking, at 5s. on $3\frac{1}{8}$ tons	0	15	8
Freight to rail on concentrate	2	0	0
Freight to port by rail (as above)	0	11	3
Bags and bagging (as above)	0	7	0
Freight, sampling, assay, &c., in Sydney (as above)	0	10	0
(approx.)	£12	0	0

There is no apparent profit shown in this even.

Even had a profit been shown, it must be remembered, however, that no account has been taken in this statement, of the loss entailed during the mining of barren zones, or of prospecting prior to winning the so-called "pay-ore." Thus, suppose a prospecting party of two should have been working for three months before finding the 2 per cent. ore, and that the value of their labour as miners be taken at 10s. a day. Assume, also, that the so-called "pay-ore" containing 2 per cent. molybdenite is worked for six months at the rate of 10 tons a month, at the expiration of which time another barren zone is met. The cost of this three months' prospecting work would have to be set down as costs in addition to those supplied in the lists above.

In the foregoing estimate the production has been put down at 10 tons a month, and this seems a fair to generous estimate of the work done on certain pipes of New England, which are of moderate size, say from 4 to 5 feet across.

In the case of a large pipe, say 20 feet diameter, the cost of mining and development might be taken at £1 10s. or £1 15s. a ton, but such pipes are rather rare. The much cheaper mining of the true quartz veins containing molybdenite is considered at a later stage.

Pipe-mining also labours under another difficulty, namely, that of remaining always on the ore body without risk of losing it temporarily.

In the next case, suppose the prospectors to be so disheartened by the cost of freight to, and the treatment charges at, a Customs' plant, that they decide to erect a plant at the mine. In this case it may be assumed that there are a number of small pipes, say, ten or twelve, under several distinct controls, in the locality from which supplies may be expected. Reference to this individual control, insomuch as it affects the financial part of the treatment, is considered later.

To this end a boiler and engine (or oil engine), rock-breaker, rolls (or ball-mill), and a 6-inch unit of mineral separation plant, as also a couple of tables for saving bismuth or wolfram, are procured Suppose the mill has a capacity of 3 tons a day per day of 8 hours, or a capacity of 12 tons per day of three shifts. Assume that the supply of ore gives a continuous run for the plant for four years at one shift a day, or say 3,500 tons. With a three-shift day this ore should be treated in one year. In the accompanying rough approximation of costs the plant is assumed to work three shifts a day and 300 days a year.

A manager might be employed at £7 a week, a concentrator for each shift at 12s., an engineer at 14s. a shift, a labourer at 9s. 6d. a shift, and a boy at 6s. a shift, in all about £2,000.

Firewood may be estimated at 12s. 6d. a cord, and one cord should give enough power during a shift, or about 2s. 6d. a ton of ore treated. Repairs may be set down at 1s. a ton, oil for flotation at 9d. a ton, royalty at 5 per cent. on value of mineral recovered

The cost of the plant must be written against the value of the ore contents, as it would be impossible to guarantee any profitable sale or disposal of the plant after the treatment of the available ore.

Among certain engineers experimenting with molybdenite concentration it is considered, at the present time, that there is a heavy fixed loss in the present method of treating molybdenite even with the use of oil in the treatment. For this reason it is considered inadvisable to feed ore into the mill at a grade less than 3 or 4 per cent. molybdenite unless the ore is not amenable to hand-picking.

The ore may be assumed to be picked by hand to the 5 per cent. molybdenite standard for a recovery of 80 per cent., thus $6\frac{1}{4}$ tons of crude ore are needed to produce one ton of 5 per cent. concentrate. Of this, 90 per cent. may be assumed to be saved by the Mineral Separation process with a sub-aeration attachment.

A table of costs may be prepared at this stage :—

	£	s.	d.
Mining costs on 21,000 tons of ore, at £2 10s. a ton	52,500	0	0
Picking 21,000 tons to 3,500 tons, at 5s. a ton, say	5,250	0	0
Power on 3,500 tons, at 2s. 6d. a ton	437	10	0
Repairs on 3,500 tons, at 1s.	175	0	0
Oil on 3,500 tons, at 9d.	131	5	0
Labour on 3,500 tons	2,200	0	0
Royalty on 3,500 tons of 5 per cent. ore, at £4 13s. 4d. a unit, recovery 90 per cent.	3,675	0	0
Cost of plant	2,000	0	0
Transport, sampling, assaying, &c., on 160 tons of concentrate, exceeding 90 per cent. molybdenite, say	500	0	0
	£66,868	15	0

Total estimated cost, £67,000.

The 21,000 tons of ore may be expected to yield ·72 per cent. by weight of molybdenite, or 15,120 units, which at £4$\frac{2}{3}$ a unit yields £70,000 approximately, thus indicating a slight profit on the undertaking, but indicating none if the usual 10 per cent. margin be allowed for safety.

This calculation is intended only as a guide, and does not pretend to be complete, inasmuch as certain unwarrantable assumptions have been made, and, moreover, certain necessary costs have been neglected. The unwarrantable assumptions in the above calculation are :—

1. The assumption of control of all these pipes without payment by the owner of the plant.

2. The assumption, as an alternative to No. 1 assumption, of a guarantee, on the part of the owners or lessees of pipes, of the ore quantities necessary for a continuous running of the plant at full capacity.

If the owner of the plant wished to secure the control of the pipes themselves, it is almost certain that the former holders would not sell their rights under many thousands of pounds.

If, on the other hand, he should depend upon the individual pipe owners for supplies of ore, each pipe being small, he must then depend, as a rule, upon the goodwill and the physical strength of the lessees as his only guarantee for supplies. For example, the individual small miner holding the lease of a " pipe " may wish neither to work continuously nor at high pressure; he may fall sick, or he may be discontented with results and may refuse to supply more ore. The mill owner would expect also to lose much time, and thereby increase his costs greatly, by treating small parcels from each pipe separately.

The assumption of a supply of ore sufficient to keep such a plant running for twelve months is a most risky one. The only localities where an amount such as this may be expected with any show of reason are Kingsgate (Yates' properties), Whipstick, and Yetholme. Yetholme deposits, however, are not "pipes."

In a case where a plant cannot be run continuously, or at its full capacity, the venture must end in great financial loss.

In the next case, suppose the ore to contain 2 per cent. molybdenite. Then, on the assumptions as above, a good profit is indicated.

The only safe method, however, for the prospector to adopt in the early stages is to concentrate the crude ore in a moderate degree by hand-picking or with inexpensive machinery, and to send it to one of the several purchasers or concentrators of such ores in the State.

Conclusion.—Having regard to these various estimates, it is extremely doubtful whether a prospecting party could work a pipe from 3 to 6 feet diameter, and containing only 1 per cent. molybdenite, at a profit, even provided the ore be free from impurities, such as pyrites, zinc, lead, or copper.

Pipes may be of pegmatite, of very siliceous granite, of garnet and quartz,, or of micaceous material containing quartz. These formations have directions and size very similar to those obtaining in quartz pipes, but they are much more difficult, hence more expensive, to prospect, because of the distinctive appearance of the quartz in a granite setting as compared with the granitic and finely-textured pegmatitic gangues, which are not decidedly distinct as compared with the siliceous granite country.

(*b*) Prospecting True Veins containing Molybdenite.

Quartz Veins.—True veins of quartz containing molybdenite have been found and worked at Moonbi, Black Range, near Bega, Warrell Creek near Macksville, Oban in New England, and at the Haystack Mountain, 17 miles south-east of Bonshaw.

These veins are as well defined as true gold-quartz lodes, and the prospector of gold-quartz lodes would experience very little difficulty in exploring such deposits.

The prospector of gold veins, however, is likely to be misled by the molybdenite contents. Being accustomed to prospect for gold in quartz he is inclined to over-estimate the amount of molybdenite present.

Let it be assumed that the quartz vein can be traced for 400 feet along the surface, that the vein has an average width of 18 inches, that the gangue is clean, and that the mine is 350 miles from a port, 330 of which are by railway and 20 by road, the last 4 miles being across hilly and rugged country, so that the freight by team is, say, £2 10s. a ton.

First—that the ore contain 1 per cent. molybdenite, and that it be hand-picked to 5 per cent. molybdenite, with a recovery of 80 per cent. of this mineral.

Second—that the ore contain 2 per cent. molybdenite and be picked to 5 per cent. molybdenite.

Both of these products are assumed to be despatched to Sydney.

Third—that the ore contain 1 per cent. molybdenite and be treated at a local plant after being picked to 4 or 5 per cent. molybdenite.

Fourth—that the ore contain 2 per cent. molybdenite and be treated at a local plant after being picked to a 4 or 5 per cent. standard.

1. This is the case of a vein of quartz 18 inches in width and containing 1 per cent. molybdenite.

In a case such as this the surface indications, namely, the persistent and well-defined outcrop of a vein with definite walls for a horizontal distance of 400 feet, are extremely favourable for the expectation of continuation of the

vein to a considerable depth from the surface. The reason for this belief is supplied on a subsequent page. Mining work may in this case, therefore, be laid out in advance with a certain measure of confidence, in striking contrast to the slow, laborious, uncertain, and expensive, methods of mining necessary in working " pipes " of ore.

As in gold, silver, copper, lead, and zinc lodes, it is probable, in the highest degree, that the molybdenite occurs in shoots, occupying, say, only a portion of the vein or lode. In this case, however, it is assumed that the vein has an average content of 1 per cent. molybdenite.

Suppose the vein to be developed by the sinking of two shafts 200 feet apart, and that two levels be driven on the vein, one at 100 feet and another at 200 feet, below the surface, and that the drives extend along the whole 400 feet of vein.

Then the average cost of sinking the shafts may be estimated at £3, and the cost of driving at £2 a foot. The total cost of development may be put down at £2,800, and the cost of stoping and raising the ore may be estimated at £1 a ton. The total weight of ore in the block worked may be estimated at 9,250 tons, which has cost £2,800 for development and £9,250 for mining, or a total of £12,000 approximately to raise it to the surface under the most favourable circumstances, namely, the uninterrupted and continuous nature of the work, thus dispensing with the heavy cost of intermittent working, the heavy interest charges against capital, and the depreciation of machinery through lack of use.

If the ore be picked to 5 per cent. molybdenite for a recovery of 80 per cent., then $6\frac{1}{4}$ tons of crude ore need picking to secure 1 ton of 5 per cent. concentrate, that is, the mine may be assumed to produce about 1,500 tons of 5 per cent. concentrate. The picking of this ore may be put down at 5s. on each crude ton or about 30s. on each ton of concentrate. The carriage on each ton of concentrate is assumed at £2 10s. to the railway and about 14s. by rail. Bags and bagging may be put down at 6s. a ton of concentrate, while carriage, sampling, and assaying, and so on, in Sydney may be taken at 15s. a ton of concentrate.

It is probable that the most favourable terms upon which this 5 per cent. concentrate could be sold in Sydney would be £2 10s. a unit, or treatment at £4 10s. a ton, no impurities such as bismuth being present.

A table of costs may now be presented.

	£	s.	d.
Mining and development on 9,250 tons	12,000	0	0
Picking of 9,250 tons, at 5s. a ton	2,312	10	0
Carriage of 1,500 tons concentrate to rail, at £2 10s. a ton	3,750	0	0
Railway freight on 1,500 tons concentrate at 14s.	1,050	0	0
Bags and bagging on 1,500 tons concentrate, at 6s.	450	0	0
Sampling, assaying, &c., in Sydney, at 15s. a ton on 1,500 tons ...	1,125	0	0
Total costs	£20,687	10	0
Total value estimated—			
1,500 × 5 units = 7,500 units, at £2 10s. = £15,000 + £3,750 = £18,750	0	0	
Showing a great loss on transaction.			

If, however, the concentrate be treated for £4 10s. a ton for a recovery of 90 per cent. of the molybdenite and then be sold for $£4\frac{2}{3}$ a ton, we have as before £19,562 for expenses to mill in Sydney, and to this must be added £1,500 × $4\frac{1}{2}$ for treatment, or £6,750, or a total cost of £26,312.

On the credit side we have £1,500 × ·9 × $4\frac{2}{3}$ × 5 = £31,500.

There is here an apparent profit shown, but it must be remembered that the customary practice is to make a 10 to 25 per cent. addition to the costs as a margin of safety. If this necessary precaution be taken, no margin of profit is revealed.

In the second place, assume the ore to contain 2 per cent. molybdenite. On this basis a handsome profit is shown after hand-picking to 5 per cent. and paying for concentration in Sydney.

On the third assumption a plant for the recovery of the ore is to be erected by the prospectors.

The cost of the plant may be assumed as before. The accompanying table of costs furnishes some indication of the cost of mining and treating ore containing 1 per cent. molybdenite. Mineral separation treatment is assumed.

	£	s.	d.
Mining and development on 9,250 tons	12,000	0	0
Picking 9,250 tons to 5 per cent. molybdenite, at 5s. a ton	2,312	10	0
Power on concentration of 1,500 tons, at 2s. 6d. a ton	187	10	0
Labour, repairs, oil, &c., about	1,000	0	0
Royalty, 5 per cent. on 1,500 tons of ore yielding 4·5 per cent. molybdenite	1,575	0	0
Transport, sampling, assaying, &c., on 75 tons of 90 per cent. concentrate, say	250	0	0
	£17,325	0	0

Total estimated value of contents recoverable is $75 \times 90 \times £4\frac{2}{3} = £31,500$.
And this shows a large margin of profit.

Or, again, a plant for dry crushing and screening may be assumed. The cost of the plant may be estimated at £1,200, and the cost of working same at 15s. a ton. The ore may be assumed to be picked to 3 per cent. at 5s. a ton for a recovery of 80 per cent. of the material, and the fixed loss by the treatment in the plant may be assumed with some degree of confidence at ·60 or ·75 per cent. molybdenite, say ·75 for purposes of computation. The grade of the concentrate may be taken at 90 per cent. molybdenite.

Table of Costs.

	£	s.	d.
Mining and development on 9,250 tons	12,000	0	0
Picking 9,250 tons, at 5s. a ton	2,312	0	0
Treatment of 2,450 tons, at 15s.	1,837	10	0
Cost of plant	1,200	0	0
Bags, bagging, transport, &c., on concentrate, say	300	0	0
	£17,649	10	0

Theoretically it might be considered that 5,550 units at £4⅔ a unit are obtainable as the result of this form of treatment, whereas in actual practice there are losses other than in the tailings, inasmuch as there is a double product from the screens, one a rich concentrate exceeding 90 per cent. molybdenite, and another which may be 40, 50, or 60 per cent. molybdenite. It would appear thus that the treatment by M.S. plant and sub-aeration machine would be the better process.

In the case of a reef, 18 inches in width and averaging 2 per cent. molybdenite with treatment assumed as above, a magnificent profit would be indicated.

The main point to be kept in mind, however, is that no lodes such as these are known definitely in New South Wales, Indeed, no lodes are known which have been proved to yield 500 tons of 2 per cent. ore to the present. The Bega

reefs are possessed of long and well-defined outcrops; their walls are well defined; they doubtless contain very large bodies of quartz; nevertheless prospecting is still at a stage so early that it is impossible to make any safe calculation as to the possible molybdenite content of, say, even 1,000 tons of ore. All that can be said with regard to these lodes is that the indications are very favourable as regards the expectation of fairly large bodies of quartz containing so-called "payable" molybdenite,

Until such time as a large tonnage of ore reserves has been actually developed it is inadvisable to erect a treatment plant, inasmuch as the cost of same has to be charged against the ore. If that ore be 5,000 tons the erection of a local plant is imperative; if it be 1,000 tons of 1 per cent. ore the erection of the plant is inadvisable; if the ore be 2 per cent. the erection of the plant is advisable; if only 100 tons either 1 or 2 per cent. in grade, the erection of a plant is suicidal.

Nevertheless, people appear to build plants with eagerness before there is any actual guarantee of ore existing in the veins or pipes. It cannot be stated too often that the cost of a plant of any service whatever would swallow up the profits from many tons even of rich ore, let alone low-grade material

Pegmatite Veins.—These have the general form of some quartz veins, but may consist of a quartz matrix in which felspar crystals are irregularly scattered; they may consist of quartz veins containing large segregations of felspar crystals; they may appear as quartz veins in which only a few felspar crystals occur, or they may occur as large interpenetrating crystals of felspar and quartz, with or without mica plates.

In New South Wales these pegmatite veins are generally very small and of very limited extension in length, width, and depth.

The largest one known to the Writer is the Coronation deposit, about 15 miles east of Deepwater.

In this pegmatite vein, the molybdenite present occurred as a segregation of large flakes associated with massive quartz and pink felspar.

Usually, however, the pegmatite veins containing molybdenite are too small and poor in molybdenite contents to justify prospecting.

(*c*) Prospecting of pegmatitic, aplitic, or graphic-granite deposits, containing molybdenite.

It is concerning this type of deposit of molybdenite, perhaps more than any other, that the prospector needs some advice. The advice, also, is practically of the nature of a warning.

The type of molybdenite here considered is very common in eastern New South Wales, and doubtless also throughout Eastern Australasia. In New South Wales, deposits of this nature occur on the Tantawanglo Mountain, in the Bathurst district, the Tamworth district (Moonbi), the Armidale district (Booroolong and Laura Creek), Elsmore, Bald Nob, Tenterfield district, and Wilson's Downfall.

The occurrences are generally large, usually from half an acre to as much as 20 acres in extent. The molybdenite, in these deposits, occurs as small flakes, or nests, in a fine-grained mixture of quartz and felspar, the quartz and felspar being interlocked as a rule, and small holes of irregular shape commonly occur throughout the mass of the rock. Quartz veins and pipes are characteristically absent, but patches of soft mica, greyish or greenish in colour, are common in many exposures. The most characteristic feature of the deposits, however, is the lack of commercial concentration of the small molybdenite flakes. Here and there a deposit is known, as at Booroolong,

which has yielded a small patch of ore averaging from 3 to 5 per cent. molybdenite, but the great bulk of the outcrops examined by the Writer would not exceed one-twentieth of 1 per cent. molybdenite. Prospectors have assured him that within these vast exposures there must be molybdenite sufficient to flood the world's market, and that all such exposures need is development " so as to get below the lean ore at the surface into the rich patches below." Shafts and holes have been sunk on these outcrops, but they have failed to reveal the existence of any defined " streak," channel, or " pipe," in which the ore might be concentrated sufficiently to repay mining and treatment costs by such method. In each case, after the most laborious prospecting, the miners appear to be farther from success than when they commenced work. In no case did they possess any clue as to the existence of a rich patch below the surface from an examination of the outcrop, inasmuch as the molybdenite flakes were scattered with a kind of regular irregularity throughout the dense granitic rock. In each case they had sunk on the most promising patch of granite in which a few more molybdenite flakes were to be seen to the square fathom than in the areas alongside, but in each case they sank in the dark, as it were, lacking guidance in the nature of quartz vein, " pipe," or pegmatite vein or pipe. Their only hope was to find a " pay-patch " by chance sinking and cross-cutting. In nearly every hole examined by the Writer these holes and shafts show no richer molybdenite concentration than is to be seen near the surface, and, unless the prospectors should light haphazard upon a rich patch, they have no hope of reward by merely working on. The explanation lies in the fact that granitic patches such as these appear to have been segregated within, or to have intruded, granitic masses during or after consolidation of the latter, and that the contained molybdenite was part and parcel of these later and more siliceous granites, and separated out as flakes throughout the cooling and consolidating stages, just as the quartz and felspar constituents had done, namely, right throughout the mass generally, in contradistinction to being formed in a vein, pipe, or large segregation. The difference between the quartz, felspar, and molybdenite, constituents of the granite, however, lies in the fact that whereas the quartz and felspar constitute about 95 per cent. of the mass, the molybdenite forms only from one one-thousandth to one ten-thousandth of the mass, except in the case of certain areas at Booroolong.

In reality the prospectors are quite right in their contention that the actual amount of molybdenite in these aplitic, pegmatitic, or graphic granite masses is immense. Take, for example, the case of exposures such as are to be found on the Tantawanglo Mountain, near Cathcart in Monaro, or at Laura Creek, in New England, where masses of rock as large as 20 acres in outcrop contain what appears to be about one two-thousandth of their weight as molybdenite. It is highly probable that the molybdenite flakes would be found just as thickly to a depth of 100 yards. Thus in a mass whose exposed portion is 20 acres, and whose depth is 100 yards, and whose molybdenite content is one two-thousandth part by weight, there are about 18,500,000 tons, and of this about 9,250 tons would be molybdenite, truly a wonderful tonnage. Nevertheless, in each ton of granite there is less than 1 lb. of molybdenite recoverable by mill treatment after careful hand-picking, and the value of the molybdenite thus recovered would be less than 4s., whereas the average mining of such ore to a depth of 400 feet on the pit principle would be 4s., while the hand-picking of such poor class ore would

also exceed 10s. a ton. To this must be added cost of treatment by milling and so on. Thus the winning of this molybdenite would cost probably ten times its value when recovered.

If, however, the prospector is bent upon examining the deposits such as are here under discussion, then he may like to know that, stated in numbers, his chance of success is less than 1 in 100. That is to say, he may explore one hundred of these deposits and not find more than one patch of "pay-ore." Moreover, such patch of "pay-ore" would doubtless be small. There are very many of these deposits in New South Wales, but not one has yielded anything approaching a profit up to the present. Booroolong probably will prove an exception to the rule.

(*d*) A few remarks concerning the occurrence of ore deposits, and true veins in particular, would not here be out of place. The Writer has seen prospectors jubilant at the discovery of mere specks of molybdenite in solid granite, or in small and scattered flakes in tiny joints, containing quartz, or as scattered flakes in hard compact pegmatites of fine texture. Hole after hole is sunk upon these poor and unpromising outcrops with unbounded faith in the idea that the tiny quartz vein, or joint, or the hard hungry granitic rock "must improve with depth," or that the scattered flakes in the cavernous granite must give place, at a certain depth, to a magnificent pipe of brittle quartz studded thickly with large crystals and plates of molybdenite. An example of such belief may here be cited. Hearing of an important molybdenite discovery about 2 miles from Tenterfield in a north-westerly direction, an inspection was made of the occurrence. The accompanying figure (Fig. 3) illustrates the nature of the molybdenite deposit. The molybdenite occurs as bright flakes, of small size, and somewhat like tinfoil or greyish-white scales, in tiny veins of quartz from a quarter of an inch to an inch in width, and of very limited length. These veins were arranged at right angles to the main trend of a tongue of aplitic or pegmatitic granite, which cuts across the "blue granite" of the district. The molybdenite scales possibly formed from 2 to 5 per cent. of the vein material.

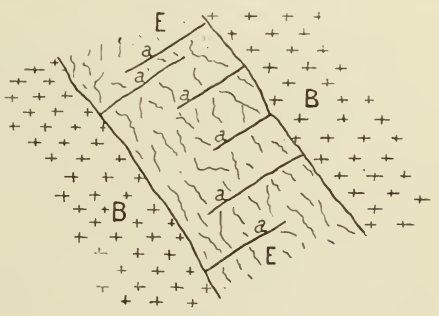


Fig. 3.

a = thin veins of quartz, ¼ inch to 1 inch wide, running at right angles to general trend of dyke. B = "Blue granite" of Tenterfield. E = dyke or tongue (5 to10 chains wide) of fine-grained sandy granite.

The molybdenite and the containing quartz in these veins at one time were evidently part and parcel of the granite dyke or tongue when it was in a fluid condition. Upon cooling the granite dyke shrunk in size, much in the same way as iron which has been molten shrinks upon cooling. In this cooling process the consolidated rock cracked at right angles to the walls of the surrounding cooler "blue granite," which had been intruded. Into the shrinkage cracks or joints thus produced vapours were expelled from the consolidated but still hot granite. These vapours contained silica, molybdenite, and other minerals. Thus upon cooling the small shrinkage joints took on the form of tiny molybdenite quartz veins.

In this particular case it is evident that there is no reason to believe that these joints would be any deeper than they were long, nor that they would become wider or richer with much increased depth.

Although the idea that molybdenite veins or ore masses generally must get larger and much richer with increased depth is firmly rooted in the minds of the prospectors of New South Wales, nevertheless this idea is against all experience, and the mass of observations by competent workers lies at the base of all mining geology.

For example, if a true vein, or lode, is very narrow throughout its course along the surface, and if it is traceable only for a distance of about 100 feet, it is a matter of experience that a lode, such as this, cannot be expected to exist at depths much greater than 100 feet, and, moreover, it cannot be expected to show a greater average width with depth than it shows at or near the surface.

If the outcrop of a lode be noted to widen considerably here and there, and if it persists along the surface for several thousands of feet, it is a safe conclusion that a lode such as this may be expected to persist to great depths and that, in places, it will show decided bulges or shrinkages as it is traced downwards.

If a group, say, of fifty pipes be examined, it will be found that although each individual pipe may exhibit considerable variations in size as it is traced downwards, nevertheless the average area of all, either at the outcrops or at a distance of a few feet below the outcrops, would be much the same as the average area of all, say at a depth of 50 or 100 feet from the surface.

Again, if a large mass of homogeneous aplitic or pegmatitic granite should show an average of one-tenth per cent. of molybdenite at a depth of about 10 or 20 feet below the surface over an area of, say, one acre, then it is safe to conclude that there is very little hope of finding an average content of molybdenite exceeding one-tenth per cent. over any area of an acre which may be exposed parallel to the surface to a depth, say, of 100 feet or greater. And, still further, if the flakes of molybdenite are scattered irregularly over the surface of these huge deposits without evidence of being concentrated in large bunches, in veins, or in pipes, then there is little chance of finding "pipes," lodes, or large bunches, of rich ore at any moderate depth. The miner may sink drive and crosscut as much as he pleases, but if the outcrops of these large pegmatitic masses are unpromising and contain only a few flakes scattered irregularly without the presence of "pipes" or veins being indicated there, then the prospector would be well advised to abandon such "large low-grade deposit," because, large as it may be, it has not a concentration of molybdenite sufficient to justify its exploration.

All these estimates of commercial values are based on the assumption of the present price of molybdenite, as also on the present prices of mining and treatment.

With regard to molybdenite pipes, no one can tell to what depth they may continue, nor in how many places, nor to what extent, they may increase or decrease in diameter. All that may be accepted with safety is that they may be expected to bend in a most perplexing manner, and that the molybdenite contents may be expected to occur in patches.

Small outcrops of pegmatite in siliceous granites may be either the upper portion of "pipes" or they may be simply "bungs" or masses of irregular shape, which may die away with very little warning.

Again, if molybdenite occurs in a spare and scattered manner or in small disconnected patches throughout a mass of quartz, the prospector must expect a deposit such as this to be patchy.

If molybdenite occurs in a true vein in patches near the surface, it may be considered that the vein or lode will be patchy.

It would occupy more space than can be given in this report to supply the detailed reason for the beliefs expressed in these paragraphs, nevertheless a very brief reference to certain points in the geological history of the eastern portion of Australia may be of help to the prospector in this connection.

The coast of Eastern Australia has not been always in the same position which it now occupies. At various times the sea has extended over the whole of what is now the coastal and plateau areas of Eastern Australia, and on the floor of this sea, which was more or less shallow, flat beds of mud, sand, and pebbles, have been deposited. At various times, on the other hand, the dry land has extended to the east of the present coast of Eastern Australia.

More than once the flat beds of mud, sandstone, and pebbles, laid down thus on the sea floor have been squeezed or shoved strongly from the side, and have thus been folded into high mountains, and upon these the weather, the streams, and the waves, have played so long that their original form has gone long since. The waste derived from this action of weather, streams, and waves has gone to provide additional layers or beds of mud, sandstone, and pudding-stone to be deposited on the neighbouring sea bottom.

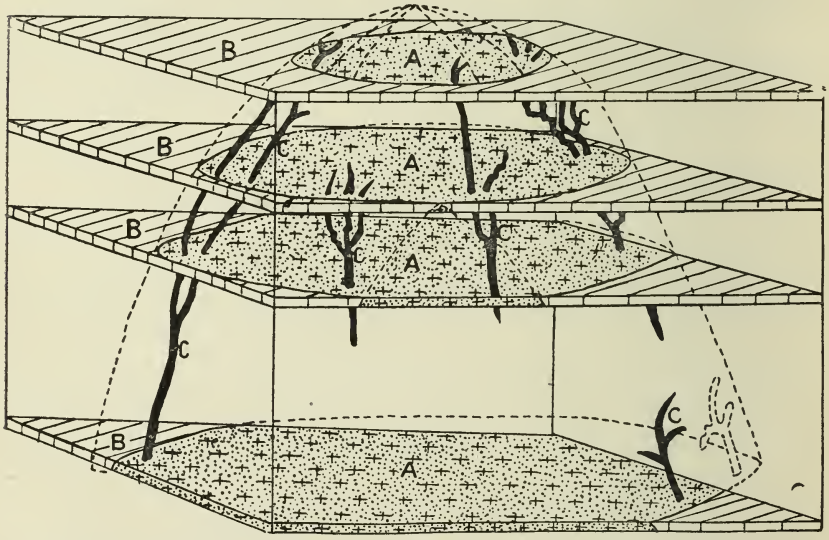
It does not concern us here as to how these flat beds were squeezed and folded so as to produce great mountain ranges at various times where previously there had been only the sea with its silt and sand; but it is of interest to us to know that, during their formation, very large reservoirs of molten rock were tapped at a considerable depth below the earth's surface in these crumpled regions, and that from these hearths or reservoirs great masses of molten rock were forced upwards into the cores, or axes, of the folded sediments. Molten rocks such as these included serpentines, diorites, and granites both of dark and light colour. These rocks, which all resemble granites, do not appear to have reached the surface and flowed out as lavas do, but they appear to have consolidated and cooled beneath a cap of slate, sandstone, quartzite, porphyry, lava, or volcanic ash. Thus a prospector walking over the surface of New England at such a period might have been walking over granites with molybdenite pipes, yet he would have had to sink through thousands of feet of slate or other rock to find them. As these granites, diorites, serpentines, and related rock types, crystallised and consolidated from the molten stage, they became smaller in volume, and in doing so they developed a whole series of zones of weakness, which appear in part to have formed joints subsequently. Along these zones of weakness, as well as along others, a gaseous or watery residue from the cooling magma worked its way towards the cooler surrounding rocks, such as slates and porphyries, which had been intruded by the granite.

In the siliceous or sandy granites these vapours or waters contained much silica, while in many cases they also contained molybdenite, bismuth, wolfram, tin, with lesser quantities of gold, silver, copper and iron. These vapours and waters gradually filled certain of the weak zones of the shrinking granite with quartz, pegmatite, and aplite, and with these also were deposited much molybdenite, bismuth, and other minerals. Many "pipes" also were formed by the action of the mineralised vapours working along intersecting joints near the margin of the sandy granites.

In Victoria and southern New South Wales, however, the molybdenite deposits are older than those which are found north of the Hunter River in New South Wales.

The mountains which we have mentioned here were worn away gradually by the weather and the streams, and plains were carved out of them near the sea level. Thus the granites, which had been hidden under a load of slate and other rocks, were exposed in the fulness of time to the light of day The low-lying plains were lifted in turn, slowly but surely, and in this way the present plateaus of Eastern Australia were formed. While both the earlier mountains and the later plateaus were being denuded, the molybdenite deposits in the granite were uncovered. As the granites were worn away so also were the molybdenite deposits which were contained therein. The associated deposits of tin, bismuth, gold, and wolfram, were also worn away at the same time. The tin and gold contents, being less perishable than the

PLATE VII.



Stereogram illustrating occurrence of pipes in the marginal portion of a granite mass. The four horizontal plates are supposed to represent plateau surfaces at various periods, thus showing how any plateau surface cuts pipes or other ore deposits at varying depths below their topmost portions.

molybdenite, wolfram, and bismuth, were carried into the neighbouring watercourses, and there formed rich shallow leads. On the other hand, the molybdenite, bismuth and wolfram, were more perishable. The bismuth and molybdenite were changed into a yellow dust, and the wolfram was changed into iron-oxide in great measure. At a later date, again, these stream deposits were buried either under floods of black lava or under thick masses of sand and clay. These formed the famous Deep Leads.

Now, in this gradual exposure of the molybdenite deposits by the action of the weather and streams after elevation of the land, it is evident that all of them were not affected equally. On the other hand some were worn away entirely, others were removed in part, while others were exposed only as to their upper portions. This is evident because the molybdenite, as also

the associated deposits, were arranged near the roofs and the walls of the high granite masses, and, as may be seen by a glance at the accompanying figure, any chance plain or plane (AB) cut through the mass, such as a plateau surface, would pass naturally through various deposits at variable heights from their uppermost portions.

The prospector thus who examines any large group of molybdenite deposits such as those at Rocky River, Deepwater, Kingsgate, Bega, or Whipstick, may rest assured that the numerous pipes or veins composing these groups have been worn down in variable degree. The tops alone of some have been worn away, while the outcrops of others are hundreds of feet below their original tops. Others again, not visible to-day to the prospector, have been worn away entirely; while others have their uppermost portions buried deeply below the surface, and it is doubtful whether any trace of them would be visible at the higher level. On the other hand, were the upper 2,000 feet of the *present* plateau and coastal masses to have been removed, it is highly probable that the molybdenite veins and pipes worked at present would have been worn away entirely. Nevertheless, it is probable that many other pipes and veins would have been found both on the upper surfaces now removed and on the deeper surface not yet exposed.

From this the prospector may understand that the more superficial portions of the molybdenite lodes, "pipes," "blows," and "bungs," exposed to-day may be taken as a fair average sample of what he may expect to find upon sinking, allowance being made for the oxidation of the molybdenite to depths varying from 5 to 30 feet from the surface.

The main lesson to be learned from this brief note is that lodes, pipes pegmatitic, and aplitic, deposits containing molybdenite cannot be expected to become either richer or larger, on the average, at considerable depths than they are at shallow depths below the present surface.

XI.—DESCRIPTION OF LOCALITIES AND INDIVIDUAL DEPOSITS OF MOLYBDENITE IN NEW SOUTH WALES.

Abington or Abingdon. *See* Laura Creek.

Adams' Claim. *See* Boundary Creek, under Rocky River.

Adams' Claim. *See* Tantawanglo.

Allies Mine. *See* Deepwater.

Amosfield. *See* Hughes' Wolfram Lode.

Angoperran. *See* Bolivia.

Appleby's Claim. *See* Bolivia.

Ardlethan.

Ardlethan Deposits.

Molybdenite occurs in the Ardlethan district in granitic rocks as an accompaniment of tin. Its occurrence, however, in the subject area appears to be merely a mineralogical curiosity.

Mr. J. R. Godfrey,* Inspector of Mines, records the mineral from Buchanan's Mine (p. 24), The Ranchero Syndicate (p. 60). Mr. Godfrey notes on p. 6, that "The tin oxide is frequently associated with bismuthinite and bismuth ochre, molybdenite, wolfram, chalcopyrite, mispickel, cerussite, pyromorphite and zinc-blende."

Mr. Geo. James, Mining Warden at Cootamundra, in a personal communication under date 25th January, 1916, states that the occurrence of molybdenite at Ardlethan "has been observed on P.M.L. 110, Parish Warri, Persse and Baker, lessees, and on the adjoining lease, 'The Outcast,' F. W. Watson, lessee. . . . There have also been traces observed at Merrybindinyala, 7 miles from Bethungra, in the form of scales in the stone."

Arsenic Blow. *See* Kingsgate.

Attunga Creek. *See* Moonbi.

Backwater. *See* Oban.

Baker's (E. A.) Claim. *See* Deepwater.

Baker's Hill. *See* Glen Eden.

Balderslie Deposits. *See* Booroolong.

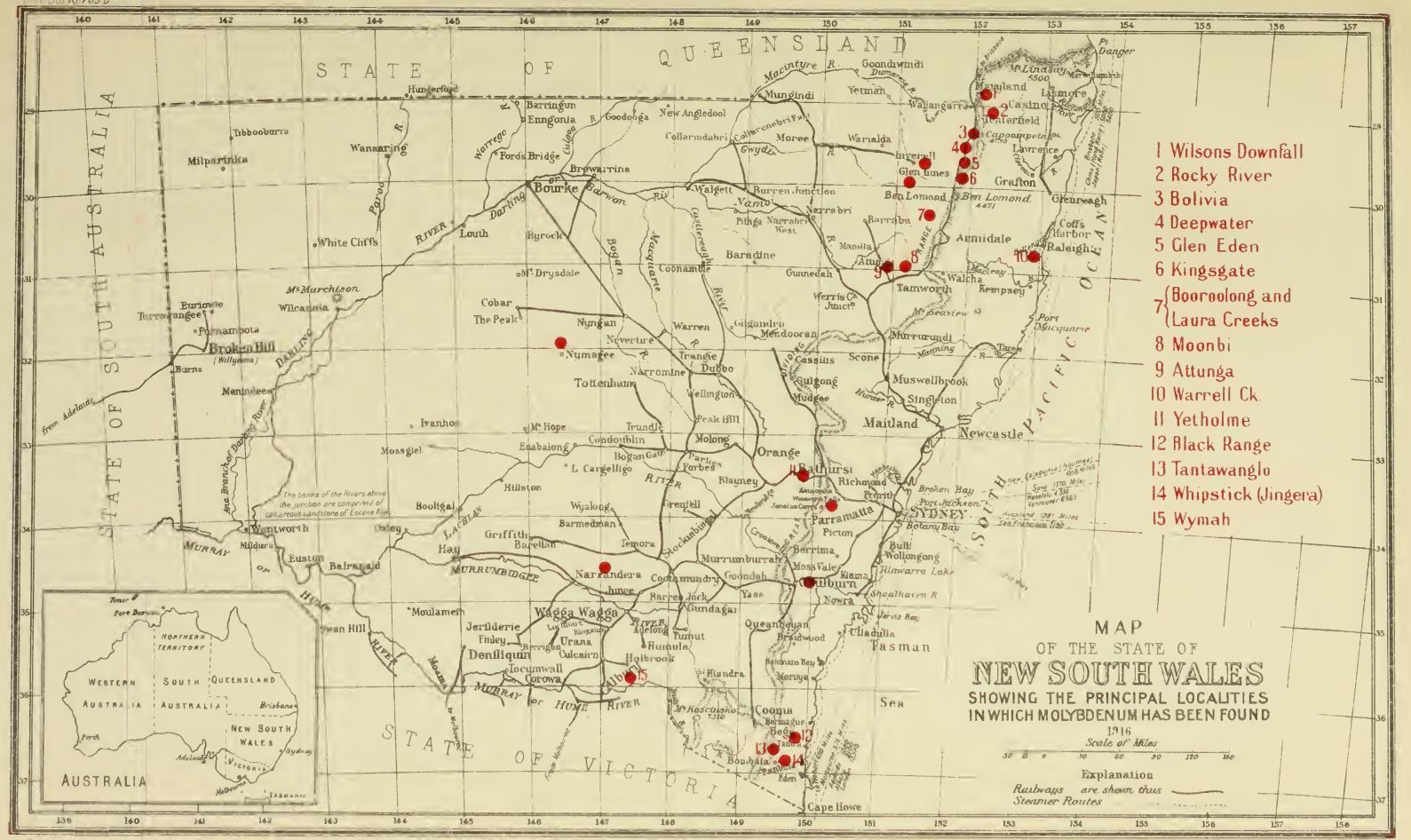
Bald Nob.

Bald Nob Deposits.

1. *Murphy and Young's Lease.*—P.M.L. 8, nearly 4 acres on Portions 35, 52, and 64, Parish Bloxsome, County Gough. Near the main road from Glen Innes to Grafton, and about 15 miles east of the former town.

Molybdenite occurs in the lease within pegmatitic granite and quartz, at or alongside an intrusive junction of finely-textured and very sandy granite with a quartz-felspar porphyry. The intrusive contact is very irregular (Fig. 4[*a*]), and a considerable amount of greisen has been developed along the general contact in the vicinity of the lease. The granite would be classed as a tin, rather than a molybdenite, type. The outcrop containing the molybdenite is large, and is composed of a cavernous aplite or pegmatitic

* The Ardlethan Tin-field. Mineral Resources No. 20, Dept. Mines, N. S. Wales, 1915, pp. 24, 60.


STATE OF QUEENSLAND
STATE OF SOUTH AUSTRALIA
STATE OF VICTORIA
SOUTH PACIFIC OCEAN
Tasman Sea
1 Wilsons Downfall
2 Rocky River
3 Bolivia
4 Deepwater
5 Glen Eden
6 Kingsgate
7 Boorolong and Laura Creeks
8 Moonbi
9 Attunga
10 Warrell Ck.
11 Yetholme
12 Black Range
13 Tantawanglo
14 Whipstick (Jingera)
15 Wymah
Broken Hill
Bourke
Wagga Wagga
Albury
Bathurst
Orange
Dubbo
Tamworth
Armidale
Grafton
Casino
Lismore
Maitland
Newcastle
Singleton
Muswellbrook
Scone
Parramatta
SYDNEY
Wollongong
Goulburn
Cooma
Moruya
Batemans Bay
Cape Howe
Darling River
Murray or Hume River
Murrumbidgee River
Lachlan River
Macintyre R.
Gwydir R.
Namoi R.
Castlereagh River
Macquarie River
Hunter R.
Clarence River
Richmond R.
Tweed R.
Manning R.
Shoalhaven R.
Snowy Mts
Mt Kosciusko 7328
Mt Townsend 7260
Mt Bogong 6508
Mt Feathertop 6306
Mt Hotham 6182
Mt Buffalo 6500
Mt Lindesay 4500
Mt Barney 4359
Mt Warning 3800
Ben Lomond 4471
Mt Beerwah 1800
Mt Coonowrin 1400
Mt Tibrogargan 1450
Mt Beerburrum 1000
Mt Coolum 1200
Point Danger
Port Macquarie
Port Jackson
Botany Bay
Broken Bay
Illawarra Lake
Lake Macquarie
Lake George
Lake Bathurst
Lake Cargelligo
Lake Victoria
Lake Mungo
Lake Menindee
Lake Tandure
Lake Tyrrell
Lake Hindmarsh
Lake Albacutya
Lake Tutchewop
Lake Buloke
Lake Boga
Lake Charm
Lake Tyrrell
Lake Corangamite
Lake Colac
Lake Bullen Merri
Lake Gnotuk
Lake Purrumbete
Lake Keilambete
Lake Terang
Lake Wangoom
Lake Gillear
Lake Elingamite
Lake Connewarre
Lake Modewarre
Lake Murdeduke
Lake Wurdee Boluc
Lake Gnarpurt
Lake Yan Yean
Lake Eppalock
Lake Nillahcootie
Lake Mokoan
Lake Hume
Lake Dartmouth
Lake Eildon
Lake Glenmaggie
Lake Wellington
Lake Tyers
Lake Omeo
Lake Guthridge
Lake Bunga
Lake Curlip
Lake Tarra
Lake Victoria
Lake Albert
Lake Alexandrina
Lake Bonney
Lake Hawdon
Lake Cooper
Lake Callabonna
Lake Frome
Lake Torrens
Lake Gairdner
Lake Eyre
Lake Blanche
Lake Phillipson
Lake Amadeus
Lake Macdonald
Lake Nash
Lake Mackay
Lake Gregory
Lake Disappointment
Lake Barlee
Lake Carey
Lake Lefroy
Lake Cowan
Lake Moore
Lake Grace
Lake Magenta
Lake Bryde
Lake Gilmore
Lake Austin
Lake Macleod
Lake Nabberu

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granite, the mineral sought being scattered about in flakes as an original constituent of the pegmatite. There is no surface indication of any concentration of the molybdenite into veins, pipes, or bungs.

A shaft (Fig. 4 [*a*]) has been sunk to a depth of 28 feet in the drusy and sandy granite outcrop, and a hole about 6 feet in depth has been sunk in a similar granitic rock a little to the north of the shaft. These workings have prospected, in some measure, an outcrop of rock about 50 feet in length and about 15 feet in width, and throughout all of which molybdenite flakes are scattered.

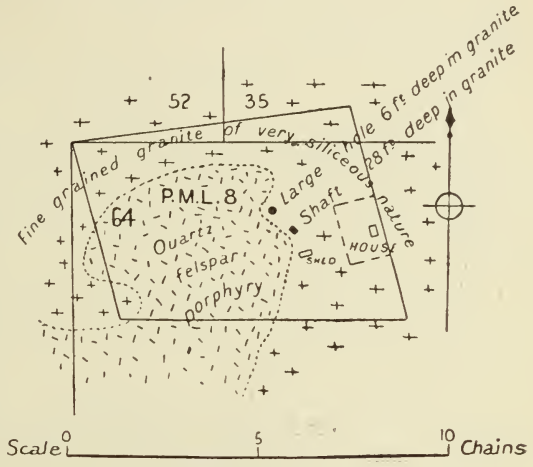


Fig. 4 (*a*).
Young's Lease.
Parish of Bloxsome, County of Gough.

As with all similar occurrences, such as at Booroolong, Moonbi, Laura Creek, Tantawanglo, and Tarana, the great difficulty encountered here by prospectors is the lack of relative concentration within some body, which could be followed with some measure of certainty, such as a vein or pipe. The deposit might be prospected by sinking vertically for, say, 50 feet, and crosscutting for 25 feet in each direction from the base of the shaft. Should no vein, pipe, or "bung," be revealed by such work, or should the average molybdenite content of the stone as mined in sinking the shaft and in crosscutting not exceed ½ per cent., then the deposit might be considered as valueless under the present conditions. It may be pointed out here that there is very little hope of finding veins, pipes, or large rich pockets, of molybdenite in these aplitic and pegmatitic phases of the sandy granite, inasmuch as they form a type to themselves, just as pipes and veins are types. The form under consideration is one which is generally large to very large, without definite shape, and one in which the molybdenite is scattered throughout the mass as a very subordinate constituent compared with the quartz and the felspar present.

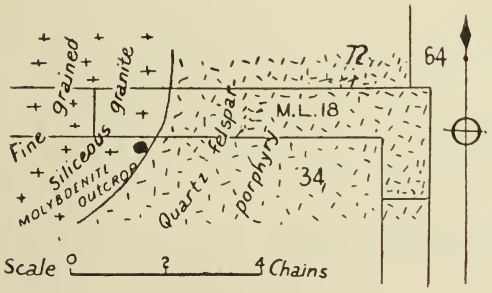


Fig. 4 (*b*).
Young's Lease.
Parish of Bloxsome, County of Gough.

2. *Young and Murphy's Claim.*—M.L. 18, 1 acre on road between Portions 34, 64, and 72, Parish Bloxsome, County Gough, about 500 yards from Murphy and Young's Lease (Fig. 4 [*a*])

Encouraging prospects of molybdenite were found on this lease in sandy granite near its intrusive contact with quartz-felspar porphyry. A considerable development of greisen occurs along the contact. The deposit is suggestive somewhat of a pipe at the surface, but very little work has been done to prove its nature. The ore occurred abundantly in the outcrop, both as yellow molybdic ochre and as flakes of moderate size in a matrix of quartz with felspar crystals.

Ballandean. *See* Tenterfield.

Bathurst.

Molybdenite flakes in granite and quartz have been recorded from various parts of this large district, to which, indeed, Yetholme (which see) itself belongs. The accompanying list of localities is a record mainly of occurrences of scientific interest only. The information has been supplied by Mr. Warden Burke.

1. Portions 74 and 107, Parish Thornshope, County Roxburgh.
2. Portions 144 and 155, Parish Bolton, County Westmoreland.
3. Portions 87 and 95, Parish Melrose, County Roxburgh.

Bega Deposits.

The Black Range Deposits.

These include the Queensgate, or Jackson's Reef, Finucane's Reef, Joseph's Reef, Scott's Reef, Gleeson's Claim, and Portion 220, all in Parish Kameruka, County Auckland.

These deposits all occur in the Black Range, about 6 or 7 miles to the south of Bega, but, owing to the roughness of the country, the deposits are best approached by a circuitous road about 10 miles in length. The undulating country around Bega consists of basic granitic rock types, which are relatively weak when exposed to stream and weather action, and the hills around Bega consist, for the main part, of dense Devonian conglomerate, sandstone, and silicified claystone.

The higher portions of the Black Range are composed, in the main, of Devonian sediments, while the gully bases and sides, in the range, commonly reveal the existence there of granite. In the range itself basic granite of the Bega type occurs, but the prevailing type is very siliceous in nature, generally fine in texture, and suggestive of a marginal intrusion into the older Bega type. At the Queensgate mine the reef occurs in the basic granite, but the reefs or lodes within the adjoining leases occur in siliceous granite.

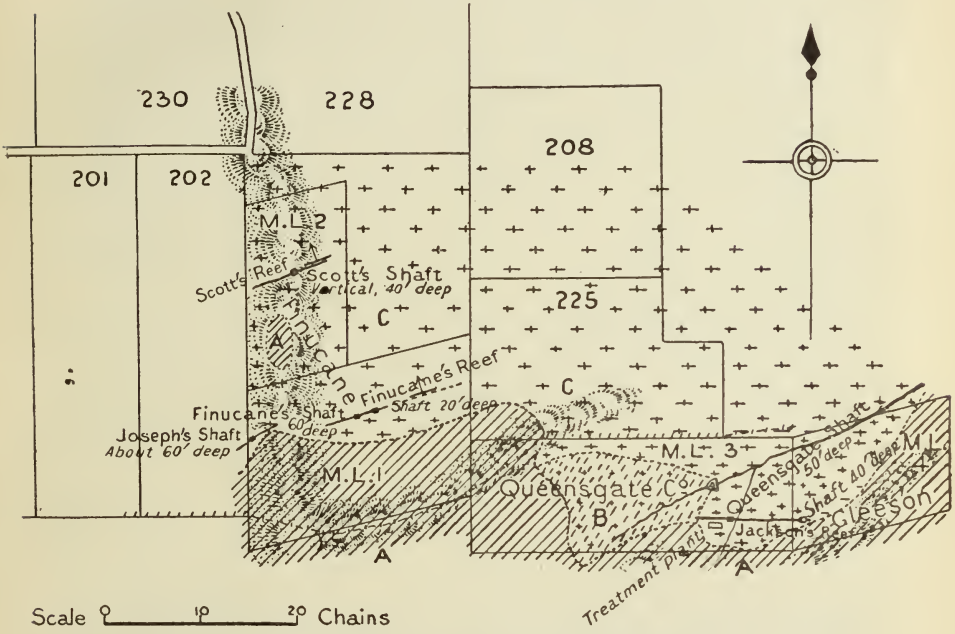
The molybdenite deposits of the Black Range are somewhat peculiar in that they occur as true lodes of considerable width, composed of compact white to translucent quartz.

The granites are post-Devonian and pre-Permo-Carboniferous in age.

1. *Jackson's Lode*, or the Queensgate Mine.—This comprises M.L. 3, of 40 acres, Parish Kameruka, County Auckland. The position of the lease, its topography, and the main geological features are indicated on the accompanying sketch map (Pl. VIII). The country is rugged and covered with brush growth. The western portion rises about 700 feet above the creek draining the lease, and is composed mainly of dense Devonian sediments. The granite containing the lode at the eastern portion of the lease is basic in nature and has intruded the sediments in a very irregular manner, forming numerous sills.

The molybdenite is contained within a true lode, which has a strike almost east and west, and a uniform and high dip to the north. The vein or lode has been traced for a distance of 175 to 200 yards along the surface, and it has a width varying from 15 to 40 inches. The vein is of quartz, dense

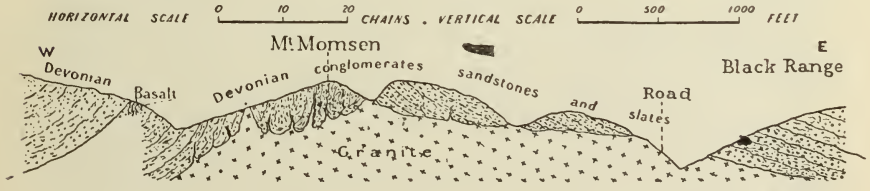
PLATE VIII (*a*).



Parish of Kameruka, County of Buckland.

A—Devonian conglomerate, grit and sandstone.
B—Sediments with granite intrusions.
C—Granite, basic in the eastern, and siliceous in the western Mineral Leases.

PLATE VIII (*b*).



[*After J E. Carne.*

and white, with very little indication of holes or vughs. Both footwall and hanging wall are well developed. A powerful set of horizontal joints occurs in the vein at distances of a few feet apart.

Throughout the quartz molybdenite occurs in a very fine state of division. The uppermost portions of the lode showed very little molybdenite, as proved by shallow prospecting holes, but a shaft, aided by the Prospecting Vote to a depth of 100 feet (P.B. Mines 15/5035), has been sunk to a depth

exceeding 50 feet from the surface, and molybdenite may be seen as though painted throughout the joints of the stone. The lode averages about 18 inches in width in the shaft. A heap of stone about 40 or 50 tons in weight had been stacked round the shaft during my visit in March, 1916. The average molybdenite content of this patch of stone exposed in the shaft has not been ascertained, but a plant has been erected at a cost of about £1,300 to treat any ore which may be found in the future. This treatment plant has been described elsewhere (pp. 12, 13) in this report. Since visiting this mine I am informed that a drive has been put in 100 feet in length, and that 75 tons of ore have been won altogether. The ore won appeared to me to contain from 1·5 to 2 per cent. molybdenite; and a sampling of the ore exposed in the drive yielded a return of 2·3 per cent. molybdenite approximately.

2. *Gleeson's Claim.*—This is included in M.L. 4, Parish Kameruka, County Auckland, and lies immediately east of M.L. 3, or the Queensgate. The lode prospected by Gleeson and Party is an eastern continuation of the Queensgate lode. A shaft had been sunk about 60 feet in depth on a lode averaging more than a foot in width. Molybdenite in fine flakes occurs throughout the stone.

The lode at Gleeson's shaft is near the intrusive granite contact, but the cover of altered Devonian sediments appears to be very thin, and the lode may be continuous in the granite below this cover.

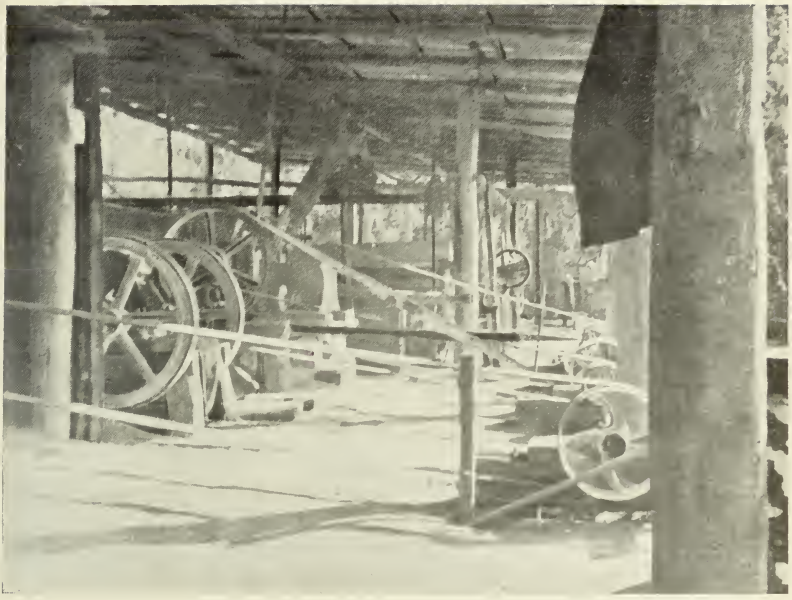
3. *Finucane and Edwards' Claim.*—This occurs within M.L. 1, a rugged area adjoining M.L. 3 to the north. In this lease the granite is very siliceous in nature, and is capped by Devonian claystone, sandstone, and cliffs of conglomerate, all gently bedded at this point. Finucane's Reef is a dense mass of quartz of white colour, having a general east and west strike and a uniform and high dip to the north (*see* Map). The lode traverses very rugged country, and has been tested by a couple of shafts and several prospecting holes. The more western shaft was sunk some years since and is about 60 feet deep, according to report, the lode exposed being from three to 4 feet in width. A shaft about 20 feet deep, and about 40 yards to the east, had been sunk on the lode, here about 30 inches wide and formed of massive quartz. Fine molybdenite occurs throughout the lode as in the Queensgate lode. A parcel of several tons was picked from the crude ore during March, 1916, and was to have been treated at the Queensgate plant. It is impossible to state what percentage of molybdenite might be expected to be won from this stone from a mere inspection of the stone.

4. *Joseph's Reef* occurs in the western portion of the lease, and is indicated on the accompanying sketch map as a powerful quartz lode, which has not been proved to contain any deposit of commercial value as yet.

5. *Scott's Reef.*—This occurs in M.L. 2, Parish Kameruka, County Auckland, adjoining M.L. 1 on the north. The lode crosses the ridge through the siliceous granite. It is composed of dense bluish-white quartz, with a strike almost east and west, a high dip toward the north, and a width varying from 4 to 6 feet. Traces of molybdenite and bismuth are reported from the Underlie, or Scott's Shaft, which is said to have been sunk on the lode many years ago to a depth of 40 feet. A softer crushed formation on the footwall side of the main lode is reported to have yielded gold and silver.

6. *Portion* 220.—This also lies on the Black Range, the granite outcropping at the base of a steep hillside capped by Devonian sediments. The granite contains molybdenite in joints near its contact with the sediments, but the prospecting work has not revealed the existence of any molybdenite deposit of commercial importance.

PLATE VIII A



[*Photo by J. W. Fawcett.*]

(*a*) Concentrating Plant at Queensgate Mine, Black Range.

PLATE VIII A

[*Photo by J. W. Fawcett.*]

(*b*) Jackson's Shaft, Queensgate Mine.

BETHUNGRA DEPOSITS.

BETTS' CLAIMS. *See* Moonbi.

BINGHI. *See* Mole Tableland.

BLACK SHAFT. *See* Yates' Pipes under Kingsgate.

BLACK RANGE DEPOSITS. *See* Bega.

BLUFF. *See* Tenterfield.

BLUFF LAND. *See* Tenterfield.

THE BOLIVIA DEPOSITS.

The general disposition of the Bolivia deposits is shown on the accompanying map of the Bolivia district. The molybdenite is found in association with two types of granite, and these two types are recognised easily by their topographical, geological, and other features.

The large granite exposure, occupying the central and western portion of the area indicated on the map, is a striking topographical feature viewed from Deepwater or Bolivia. It forms a dissected plateau with rugged slopes rising above the general level of New England at Deepwater. The Great Northern Railway traverses it by means of a long wind-gap, and descends thence to Bolivia along a steep and dangerous cutting, known as the Horseshoe bend in its lower portion. This granite is a coarse granular type, very sandy in nature, and covered with stunted and scrubby vegetation. It is the eastern extension of the Great Mole Tableland granite, which has yielded so much tin and wolfram. The molybdenite occurs all round this mass in scattered flakes, and in numerous portions in Parish Bolivia, to the immediate north of the Angoperran granite. The latter occurrences, however, are associated intimately with small outliers and dykes of aplite, pegmatite, bosses, and graphic-granite dykes belonging to the main Angoperran mass.

The Booroo or Splitter's Swamp granite is indicated on the map as the eastern portion of the area mapped. Whereas the Angoperran granite and the associated quartz-felspar-porphyry form striking topographic features, the Booroo granite appears to be sunken well below the surrounding plateaus and to form the base and sides of a wide valley. This type is not nearly so siliceous as the Angoperran type, and its vegetation is not of a type so stunted as that which the western granite supports. Molybdenite occurs along its margin in pipes of a highly encouraging appearance, whereas the wolfram granite of Angoperran carries deposits of molybdenite which are not nearly so promising in appearance.

In 1915 the Writer inspected isolated deposits of molybdenite both at Booroo, Bolivia, and Angoperran, and was at a loss to understand how one and the same type of sandy granite could present appearances and ore deposits so variable as those of Booroo and Angoperran. The intermediate country was very rugged and steep, and the prospectors did not appear to have considered the question of the possibility of the two granites being distinct. With this problem in mind a trip was made one day with Mr. A. E. Cooper, and another with Mr. Collins, of Deepwater, with the idea of determining the granite boundaries. It was then ascertained that a high and rugged bar of quartz-porphyry separated the two granite types; that the lava type had been intruded by both granites, but that they had never invaded each other's area, although in one place they were less than one

mile apart. It was then evident that the Booroo granite was not merely a phase or segregation of the wolfram type, but that the two granites were of different types.

The Booroo granite is closely allied to the Bow Creek and Kingsgate types in general appearance, in silica percentage, in topography, and in the vegetation which covers them. Moreover, they are strikingly alike in the manner of occurrence of the molybdenite pipes, although the Kingsgate types are more in the nature of true quartz deposits, whereas the Booroo and Bow Creek types are more granitic in character. This type of granite may be called the true or normal molybdenite granite.

Owing to the greater resistance of the quartz-porphyry to the agencies of denudation than the Booroo granite, the former stands above the latter in high escarpments, which are rugged in places, as at Cooper's Claim, in Portion 44. Inasmuch as the important pipes which hug the margin of the granite in Booroo occupy thus the area below the escarpments, there is a decided tendency for their outcrops to be concealed beneath the débris showered upon them by the steep porphyry hillsides. Prospecting for pipes is thus a difficult matter, and only skilled and persevering prospectors can hope for success. It may be noted that four or five pipes are shown along the junction of the Booroo granite with the quartz-porphyry, but there is no reason to believe that many more pipes do not exist along the granite margin in the long line of contact indicated in the map as stretching from Mount Capoompeta (The Magistrate) on the Main Divide to a point one mile north of Bolivia railway station.

1. *Appleby's Claim.*—About 60 yards in a direction south-south-west from the north-west corner of Portion 115, Parish Angoperran, County Gough, and about 13 miles north of Deepwater.

Molybdenite and wolfram occur here in a pipe composed of a quartz paste or base containing felspar grains and crystals, all within a coarse sandy granite of the wolfram type (*see* Map). The deposit occurs about 150 yards from the intrusive junction of the granite with quartz-porphyry. A pink granite of fine texture (tin granite) appears to have a local development in Portion 115, between the main mass of the coarse granite and the quartz porphyry.

The granite containing Appleby's deposit is a continuation to the east of the Great Mole Tableland granite, which extends continuously from a point near the Dumaresq River on the Queensland border, through Torrington to the site under consideration. The map is a continuation of the one illustrating the Vegetable Creek tin-field by Professor T. W. E. David,* and extended eastward by Mr. J. E. Carne.†

Appleby's deposit has not been prospected beyond a shallow depth. Its outcrop appeared to be about 6 feet across, and the molybdenite and wolfram ore was followed to a depth of 30 feet measured along the underlie, but only 15 feet in a vertical direction. It is stated that the deposit was prospected twenty-two years ago by Mr. Cassidy, of Deepwater, for wolfram, and only reworked at a later date by Mr. Appleby. The molybdenite occurs in crystals and flakes of considerable size associated with small and scattered lumps of wolfram.

This claim has been abandoned temporarily owing to the lean nature of the stone prospected to date.

* The Vegetable Creek District. Memoir No 1, Dept. Mines, New South Wales. 1887.

† The Tin Mining Industry. Mineral Resources, No. 14. 1911. *See* map of Emmaville District. The eastern limits of Professor David's and Mr. Carne's areas are approximately the western limits shown on the map accompanying the present report.

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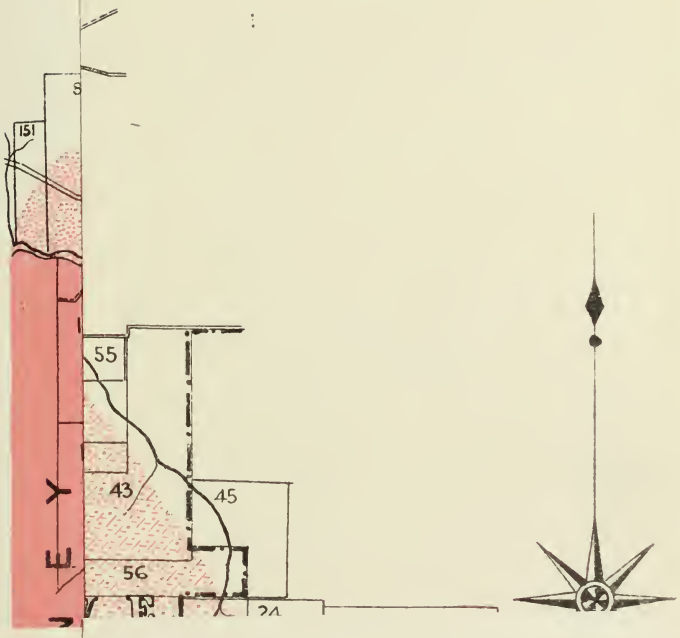
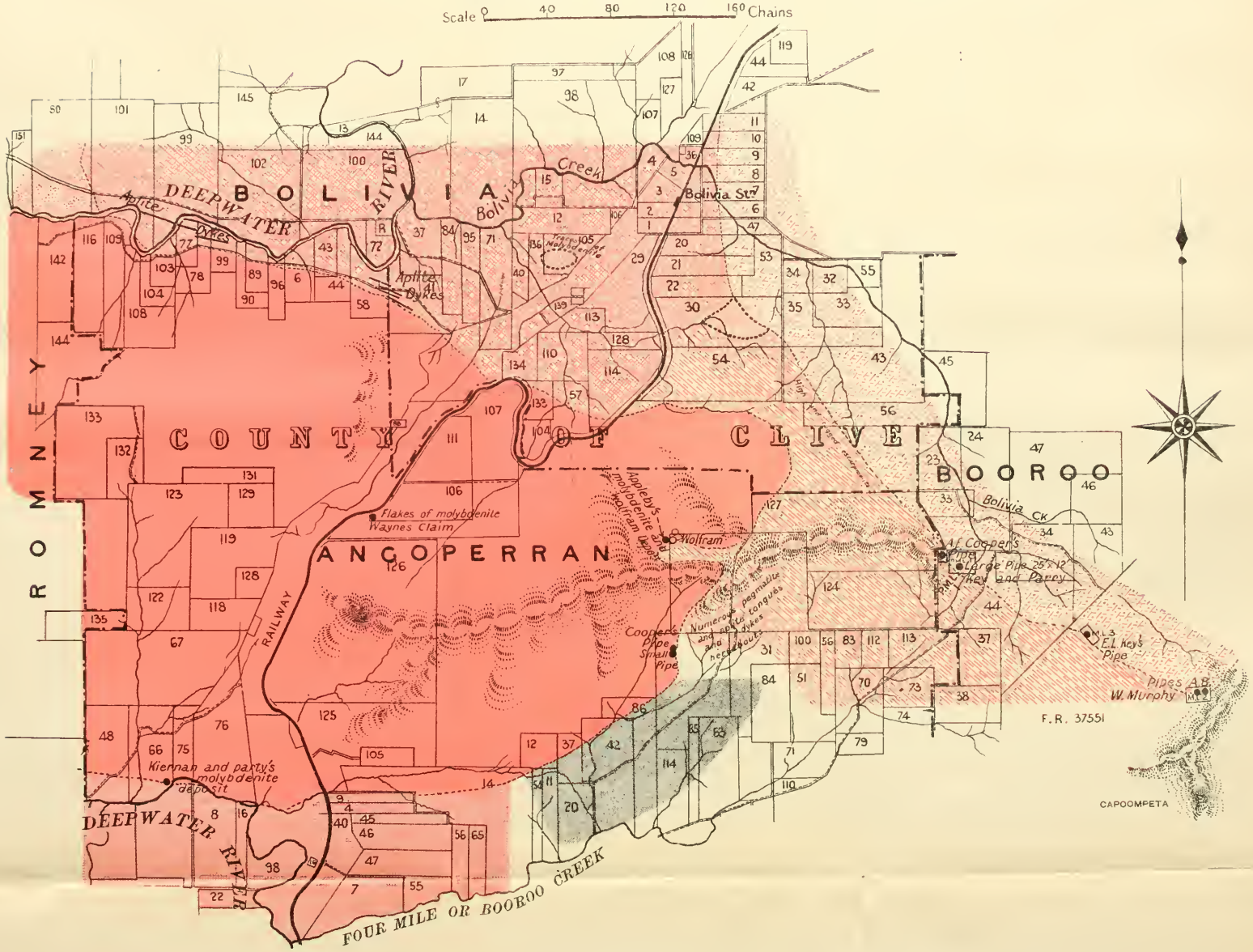


SKETCH GEOLOGICAL PLAN SHOWING THE POSITION OF THE MOLYBDENITE DEPOSITS AT

BOLIVIA



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2. *Cooper's (A. E.) Claim, No.* 1.—Authority to Enter, of 10 acres, in north-west corner of Portion 72, on W. A. F. Potter's C.L., Parish Angoperran, County Clive. This is shown on the map as being a little to the north of Portions 86 and 114, Parish Angoperran.

Molybdenite occurs here in pipes of felspar either in granular masses, or the pipes may be composed of a quartz base studded with felspar crystals. All occur in a coarse sandy granite alongside its intrusive contact with quartz-porphyry. The granite near its junction with the porphyry for a distance exceeding 400 yards is dotted with small pipes and patches of granite containing flakes of molybdenite.

A peculiarity of these pipes and patches of molybdenite ore is one common to nearly all the deposits examined in the tin and wolfram granites of New South Wales, namely, that they do not *appear* to be replacement products so much as segregations in their siliceous host. The Tantawanglo, Booroolong, Moonbi, Bald Nob, Wilson's Downfall, and Maryland pipes, aplites, or pegmatitic masses, all furnish examples. The pipes themselves, of these tin and wolfram granites, *may* be replacements, but they give little evidence of such origin from the mineralogical viewpoint, whereas the pipes of the molybdenite granite are very suggestive of replacement action.

One of these pipes on Cooper's Authority has been prospected for a vertical depth of 21 feet. The lower portion of the vertical shaft sunk upon the pipe was filled with water during the inspection in 1915, but the heap of stone lying on the surface at the shaft mouth contains many specimens of molybdenite of promising appearance from a prospecting point of view. The pipe, however, is small, being less than 5 feet in diameter, and the granitic material of the pipe is very hard. The deposit was prospected two years ago by Mr. A. E. Cooper, who also prospected several other granitic outcrops containing molybdenite. Mr. Cooper left this area for a more promising one a few miles to the east in Portion 44, Parish Booroo.

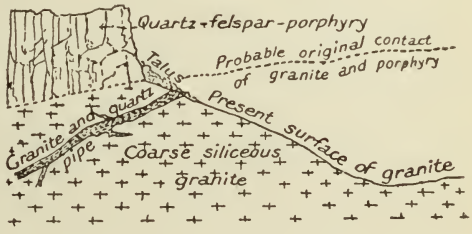


Fig. 5.

Ideal section across granite and porphyry contact in the Deepwater District.

The porphyry resists weathering better than the granite, and recedes in cliff fashion. Talus from the porphyry cliffs tends to hide the outcrops of pipes near the contact.

This deposit merits prospecting to a depth of 50 feet at least on the evidence of the stone lying on the surface in 1915.

An application to enter was taken up by another prospector on Portion 72, immediately to the south of Cooper's Authority. Molybdenite was found here in scales and scattered flakes in the wolfram granite near its intrusive junction with the quartz porphyry.

3. *Cooper's (A. E.) Claim No.* 2, or the Sunrise Mine.—P.M.A. of 6 acres, at north-west corner of Portion 44, on E. L. Key's C.L., Parish Booroo, County Clive. About 13 miles north-east of Deepwater and at the head of Splitter's Swamp (*see* Map).

The deposit is a granitic or pegmatitic pipe containing masses of crystallised and jointed quartz forming a kind of discontinuous core to the deposit.

It occurs in the sandy Booroo granite near its intrusive contact with a dense quartz-felspar porphyry (Map). Immediately to the west of the pipe the porphyry rises in high cliffs and very rough escarpments (Fig. 5), which extend north-west with more subdued slopes in the direction of Bolivia railway station and in a south-easterly direction towards the Main Dividing Range, at Mt. Capoompeta, 5,100 feet above sea-level. The main range near this point is composed of quartz-porphyry as lavas and breccias. The great topographic prominence of the porphyry is due to its comparatively great power of resistance to stream and weather action as compared with the Booroo granite. By this factor an additional difficulty has been introduced into prospecting operations for molybdenite in this area, for, inasmuch as the pipes are arranged along the margin of the softer granite, they are generally covered with débris which has fallen on them from the dominating cliffs and escarpments of porphyry. Especially is this the case upon, and immediately to the north of, Cooper's Authority.

Mr. Cooper, in prospecting near the foot of the porphyry cliff, found several small fragments of quartz or pegmatitic material peculiar to the pipes of this district. In these fragments he noticed yellow stains of molybdic or bismuth ochre and a few specks of molybdenite. These rare fragments were mingled with large blocks of porphyry. After clearing away the overburden of porphyry and soil the outcrop of a pipe was found, and the pipe itself was then followed at a very low angle for a distance exceeding 70 feet towards the adjoining porphyry. This low inclination of the pipe suggests the probable flat nature of the intrusive granite contact at this point.

The gangue of these granite pipes, both at Splitter's Swamp and at Bow Creek and the Allies, is peculiar, and the mineralogical composition of Cooper's pipe may be taken as typical of some of the others. The quartz forms a sort of glassy base, in which felspar crystals may be isolated or crowded together. The gangue in places also appears to be a massive and granular felspar, but in many instances it is simply an aggregate of tiny quartz and felspar grains intimately associated with each other. Masses of material also occur in the pipes suggestive of kaolin, and this appears to have arisen from a decomposition of the felspar. Considerable amounts of soft hydrous mica as masses of fine scales are also common. The molybdenite occurs typically in large but thin ragged flakes, in places crowded thickly together. A fine sample of the better class molybdenite ore from Cooper's mine is on exhibition at the Mining Museum at Miller's Point.

As with all other granitic pipes, the one under consideration has been found somewhat difficult to follow. Near the outcrop a quartz branch or pipe, about 3 feet in diameter, was followed almost vertically for a few yards, but work on this deposit was discontinued owing to the low grade of its mineral contents as far as revealed by the prospecting. The main pipe at this point was about 5 feet in diameter and contained much molybdenite and bismuth slugs and grains, the latter mineral being reported to be more abundant in the lower portion of the pipe. Patches of quartz accompany the pipe, especially in its upper portion. This feature also is one that appears to be common in the New England granite pipes. True coarse pegmatite containing large quartz crystals is a feature not uncommon.

The ore is clean, the gangue containing little else than quartz, felspar, or "kaolin." The bismuth and molybdenum sulphides are much oxidised to the greatest depths reached at present in Cooper's pipe

During the inspection of the mine in 1915, the face was in low-grade ore, and the pipe appeared to be constricted locally. This condition, however, is one which must be expected at various points in these deposits, and the prospector can only follow the ore body, maintaining a sharp watch all the while for branches or so-called "droppers" so as to avoid the possibility of overlooking the main pipe. The deposit appears to be a valuable one.

Mr. Cooper has applied for an additional Authority adjoining P.M.A. 2.

Treatment.—Mr. Cooper makes a rough concentration by crushing the ore with horse rolls, by means of power from a 9-feet iron rod working a 3-feet drum, in conjunction with a 4-inch pin on wheel. The material so crushed is sieved dry by hand. The grade of the crude ore is not known. Value of plant, £70 in 1915.

Production, 1915.—1 ton 2 cwt., valued at £438 10s. 6d.

Production, 1916.—Mr. Cooper informed me, in February, 1916, that he had just sold 18 tons of bismuth ore at the rate of £8 10s. a ton at the mine, and that he had also produced 24 cwt. of molybdenite.

4. *Fearnside and Fletcher's Claim.*—Authority of 40 acres on Portion 160, Parish Bolivia, County Clive. Molybdenite in sandy granite near its contact with other rock types, according to Mr. George Smith, Inspector of Mines [P.B. 15/3330 Mines].

This appears to be the same place which was shown to me by Messrs. Meredith Brothers in 1901, and reported upon as follows in Mineral Resources, No. 11, p. 10:—

"Apparently a small quartz 'pipe' (?) was located which contained a very limited quantity of molybdenite. This was sunk through near the surface and the shaft was continued in granite. At the bottom a little driving was done also in granite. No ore is showing in the quartz where it was passed in the shaft."

5. *Horseshoe Bend.*—Messrs. Wayne and Hamilton have found flakes of molybdenite in the wolfram granite in Portions 107 and 111, Parish Angoperran, County Clive, 2 miles south-east of railway station. The molybdenite content is very small. Occurrence: Molybdenite in quartz, as a segregation from coarse sandy granite near contact with blue granite. The attention of the author was drawn to this by Mr. Joseph Stevens about twelve years ago.

6. *Key's (E. L.) Claim.*—M.L. 3 of 8 acres on Crown lands about 2 miles to the south-east of Cooper's Pipe, in Portion 44, Parish Booroo, County Clive (Map).

The occurrence is of the nature of a pipe in sandy granite about 20 yards from its intrusive contact with quartz-porphyry (Map). The minerals sought are molybdenite and bismuth.

The pipe dips towards the porphyry at an angle of 70 degrees. The greatest depth reached during September, 1915, was about 30 feet. The pipe was fairly uniform in size to that depth, and was about 12 feet by 7 feet in cross section. The gangue consisted of a quartzose granite mixed with a pegmatite or glassy quartz base containing felspar grains and crystals, both isolated and crowded together. Large masses of quartz, of irregular shape, also occur in the pipe so as to form a sort of core to the pipe. This discontinuous core of quartz is a feature common to certain granitic pipes. Molybdenite occurs abundantly in flakes and leaves, while bismuth occurs both in the native and sulphide forms, but it is quite subordinate in amount to the molybdenite.

The prospects of this pipe were fairly good as judged by the appearance of the bottom in 1915.

Production.—1914, not known.

1915.—Small.

7. *Key and Parry's Claim.*—P.M.L. 1, of 20 acres, taken up in the name of E. L. Key, Portion 44 within Key's C.L., Parish Booroo, County Clive, adjoining A. E. Cooper's Authority on the south-east and about 1½ miles north-west from E. L. Key's pipe. (*See* Map.)

The deposit known as Key and Parry's pipe outcrops in the coarse sandy granite of Booroo, about 60 yards from its intrusive contact with the quartz-porphyry. (*See* Map.)

The accompanying notes on the general geology of the important deposit here considered deal only with the period prior to October, 1915. A considerable amount of prospecting has been carried out since that date.

The pipe was found in June, 1914, by two prospectors, Messrs. E. L. Key and J. N. Parry, who noticed a large outcrop of white quartz on the rough hillside and about 60 to 70 yards from the porphyry escarpment to the south-west. Traces of molybdenite also were seen in the surface stone. The outcrop, when cleared of débris, was found to be about 25 by 10 feet in cross-section, and it was composed, in the main, of white quartz. A plat was excavated here in the hillside, the deepest part of the excavation being about 10 feet in depth. A shaft was sunk in the pipe from the deeper part of the excavation. The shaft was vertical for a depth of 25 feet from the plat, and the deposit appeared to be between two decomposed dykes. It appeared also to have formed a "step-and-tread" here, as the floor of the workings at this portion of the mine is almost flat for a short distance, passing into a continuation of the vertical shaft for 10 feet additional depth. A dyke here also appears to form one wall.

At a depth approximately of 45 feet from the surface the pipe was followed on an underlie approximately of 45 degrees for a distance of 45 feet. A large mass of quartz was left underfoot at this point of change, from a vertical to an inclined direction, the "hanging-wall" being followed for the rich molybdenite it contained. Bismuth was present only in subordinate amount. Thin veins carrying molybdenite accompanied the deposit, along joint planes. The pipe rock, as seen in the lowest workings, consisted of quartz, bluish-white in colour, of pegmatitic material or a quartz-base containing felspar grains and crystals. Patches of decomposed pegmatite and soft mica appear to be common, and rich molybdenite was to be seen in flakes and masses throughout both this decomposed material, the quartz veins and patches, and the quartz base with felspar crystals.

The deposit was large at the deepest point reached in September, 1915, and there appeared to be no sign of a constriction of the deposit. All the same, it seems strange that the prospectors have left a massive patch of quartz unprospected such as that seen at the point of change of inclination of the pipe, about 45 feet from the surface. At Kingsgate, the quartz pipes are followed, preferably along the "footwall" side, because the main bismuth content is found there (p. 96). It would be advisable at least to prospect the patch of quartz just mentioned, as also to tap the "footwall" portion of the pipe from point to point. Care should be exercised, generally, to strip the walls as cleanly as possible of ore, otherwise important branches might be overlooked.

In 1914 a small plant for treatment was bought at a cost of £70.

Production, 1914.—1 ton 8 cwt. of concentrate, containing 93 per cent. molybdenite, was won from 28 tons of ore, by rolling and sieving. The value of the concentrate was £668.

1915.—700 tons of ore raised. Estimated to contain $3\frac{1}{4}$ tons molybdenite concentrate. Valued at £1,376. Plant valued at £120.

The prospects of this deposit in 1915 appeared to be very hopeful, and it is well worthy of further development.

8. *Kiernan and Party's Claim.*—Authority to Enter within south-eastern portion of Portion 66, Parish Angoperran, County Clive, on the Deepwater River (*see* Map), about 8 miles from Deepwater, and about 8 miles from Bolivia railway station by road.

Molybdenite occurs here in a pegmatite within a granite tongue intrusive into an altered andesite. The pegmatite consists mainly of a mass of quartz in which isolated crystals of felspar occur. The main mass of the granite is coarse, but the tongue containing the molybdenite deposit is very fine in texture (tin-granite).

The deposit was known many years ago by Mr. A. E. Moule, a former owner of portion 66. The deposit was prospected by J. Stapleton about the beginning of the year 1910, and at a later date by Kiernan and party.

The outcrop is rather small, and it may represent the upper portion of a pipe. Very little prospecting has been done to prove either its nature or the value of its contents, the largest hole sunk on the outcrop not exceeding 2 feet in depth and 5 or 6 feet in length. Large flakes of molybdenite occurred in fair abundance near the surface. The rock is very hard and costly to mine, nevertheless the deposit is worthy of a better trial than it has had up till the present.

Like so many other molybdenite deposits found in the wolfram and tin granites, it is one that should only be worked as a prospecting claim, say by a couple of miners who might test it to a depth of 20 or 30 feet by sinking.

9. *Murphy's (W.) Claim.*—M.L. 2 of 16 acres, on Crown land, Parish Booroo, County Clive, at the head of Splitter's Swamp or Bolivia Creek, in very rough and mountainous country, about 7 miles from Bolivia railway station and 14 miles from Deepwater (*See* Map.)

The occurrences are pipes containing molybdenite and bismuth in the Booroo granite alongside its contact with quartz-felspar porphyry. This granite and porphyry contact is the continuation to the south-east of that junction near which Key's, Key and Parry's, and Cooper's pipes have been found. These features are illustrated in the south-eastern portion of the map.

The main deposit on the lease is a large granite and quartz pipe in the coarse Booroo granite. Immediately to the south of the pipe the porphyry rises steeply to the summit of the Main Divide at Mt. Capoompeta, 5,100 feet above sea level. The outcrop of this pipe was very large and had the appearance of opaque white quartz. The greatest depth reached in September, 1915, was about 30 feet from the surface and the longer measurements across the bottom of the workings were about 20 feet by 15 feet, all in pipe rock. The gangue consisted in part of dark, granular, and cavernous quartz, in part of quartz containing massed or isolated felspar crystals and grains, and in part of a white, brittle, massive or crystallised quartz. Magnificent specimens of crystallised molybdenite were seen in both massive white and crumbling dark and granular quartz. Native bismuth also may be seen in the dark granular variety of quartz. A fine specimen of the richer ore is on exhibit at the Mining Museum at Miller's Point.

Fig. 6 illustrates the general association of the minerals.

The prospects of this pipe appeared to be very hopeful in September, 1916, and it is well worthy of further development.

Another quartz and granite deposit occurs in the granite as indicated at B on the map. Encouraging prospects of molybdenite were found in the outcrop, but surface work only has been done at this spot.

A large quartz wedge, or lens, occurs at the contact of the granite and the porphyry, but little or no trace of molybdenite or bismuth has been found in the outcrop. No work has been done on this exposure.

Production, 1914.—Nothing recorded.

1915.—No returns available.

1916.—Small parcels of ore of unknown quantity won.

Aid granted from Prospecting Vote, P.B. 16/3654 to test the deposit.

10. *Wayne and Hamilton's Claim.*—Authority to Enter on Portion 106, Parish Angoperran, County Clive. Molybdenite in small flakes in small joint planes and tiny quartz veins, by Mr. L. Wayne, in a very hard, coarse, reddish, and granular, alongside the Great Northern Railway line, on the eastern side of the railway fence. The deposit is about a mile and a half distant from the nearest known intrusive contact of the coarse wolfram granite in which it occurs. The deposit, however, has only a scientific interest owing to the smallness of the veins, the leanness of the ore, and the hardness of the granite gangue. Moreover, there is no reason to expect the prospects to improve with increased depth.

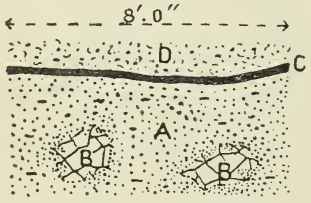


Fig. 6.

Sketch section of detail of Murphy's pipe seen in 1915.

A—Dark granular quartz containing molybdenite and bismuth.
B—Irregular patches of massive and jointed white quartz.
C—Vein about 1 inch thick containing rich molybdenite.
D—Quartz paste with felspar grains and crystals with molybdenite and bismuth.

11. Molybdenite flakes have been reported also from the following areas, but in each case they appear to have little commercial value. They are associated with aplite, pegmatite, and granite, bosses and dykes, traversing the blue granite and associated rocks to the north of the Angoperran granite.

On the map an interesting hill or outlier of aplitic and pegmatitic granite is shown in Portions 105, 136, Parish Bolivia, about 1 mile south-west of Bolivia railway station. Small patches of pegmatite and quartz with molybdenite flakes were seen round the margin of this in 1902 by the Writer. Dykes also of aplitic rock extend from this knob into the surrounding "Blue Granite."

Angoperran (Parish). Portions 103, 104, 106, 107.

Bolivia (Parish). Portions 12, 18, 40, 70, 105, 136.

These portions are indicated on the accompanying map. The molybdenite deposits on them seen by the Writer are interesting only as records of localities.

In conclusion, attention might be directed to the advisability of prospecting the margin of the Booroo granite. It is doubtful whether much of value in the nature of molybdenite is to be found in the great wolfram-tin granite of Angoperran and its continuation west as the Mole Tableland and the Gulf.

Borchardt and Roos' Claim.—See Tarana, under Yetholme.

Booroolong Deposits.

The molybdenite deposits of Booroolong occur in Parish Sandy Creek, County Hardinge, at a distance of 28 miles from Armidale in a north-north-west direction. The topography is that of a plateau, the height being nearly 4,000 feet above sea level, and the surface of the upland being broken by rough, rocky hills.

The rocks composing the plateau within the parish of Sandy Creek consist, in the main, of coarse, siliceous granites and siliceous quartz-porphyries of fine texture. These granites in turn contain either segregations or intrusions of an intimate mixture of quartz and felspar, containing countless tiny holes or druses. Small and large patches of aplite and pegmatitic granite form portions of this quartz-felspar mixture. In places these aplitic and pegmatitic mixtures occur near the contact of the granite and the quartz-porphyry. At certain points these mixtures of quartz and felspar contain flakes of molybdenite as an original constituent. This phase is well seen in both P.M.A. 1, P.M.L. 1, and P.M.L. 2. In other places, as in M.L. 12, the molybdenite occurs with quartz in granite.

These deposits appear to be the best of the pegmatitic or aplitic types known at present in the State. A considerable amount of prospecting has been carried out, but nothing of commercial value appears to have been produced to the present.

A fine sample of the better class of ore produced at the Booroolong mines may be seen at the Departmental Museum at Miller's Point.

The deposits in P.M.A. 1, and P.M.Ls. 1 and 2 were the only ones examined by me in this area.

1. *McKinley's Claim.*—M.L. 12, 40 acres, Crown lands, Parish Sandy Creek, County Hardinge, about one mile south of Schaefer's and Wildblood's leases.

According to the Mining Registrar of Glen Innes, " The molybdenite occurs as flakes with quartz in granite. The quartz outcrop is visible for a quarter of a mile, but sufficient work has not been done yet to determine whether the formation is of the nature of a lode or a pipe. Prospecting operations, so far, have been confined to the surface, the greatest depth sunk being 8 feet."

2. *Macpherson's Lease.*—P.M.L. 1, of 20 acres, within Portion 10, W. Stanley's C.L. of 960 acres, Parish Sandy Creek, County Hardinge.

P.M.L. 1 adjoins Wildblood's claim on the east. The country is of siliceous granite, containing aplitic and pegmatitic masses. Molybdenite flakes are scattered throughout these masses as an original constituent. The natural concentration of the molybdenite is very low.

3. *Robertson's (E. H.) Claim.*—Authority to Enter on Portions 11 and 12, Portion 12 being F. W. B. H. Stanley's A.C.P. of 320 acres, and Portion 11 being F. W. B. H. Stanley's C.L. of 960 acres, Parish Sandy Creek, County Hardinge.

Molybdenite flakes in aplitic and pegmatitic granite.

4. *Schaefer's Deposit.*—P.M.L. 2, 10 acres, within Portion 10, being W. Stanley's C.L. of 960 acres, Parish Sandy Creek, County Hardinge, and immediately to the north-east of Wildblood's Authority (P.M.A. 1).

The lease occurs on the slopes of a rough and rocky hill of coarse aplitic granite, throughout which large masses of drusy material occur composed of intimate growths of quartz and felspar. Molybdenite flakes occur somewhat freely in patches as an original constituent of the rock. One patch of such rock, within the southern portion of the lease, may be 100 yards in length and 30 to 40 yards in width. In one portion of this outcrop numerous flakes of molybdenite were seen, and a shaft was sunk at this point to a depth of 30 or 40 feet. At the time of my examination the shaft was almost half-full of water, and it was thus impossible to examine the lower workings. Some very promising ore, however, presumably from the lower portion of the shaft, was lying near the brace at the surface, and if this ore has been obtained from the shaft it is difficult to understand why prospecting operations were stopped. To prospect the deposit the shaft might be continued to a depth of 50 feet from the surface and crosscuts thence be made at right angles to each other for a distance of 25 feet from the base of the shaft. It is possible that a rich patch of molybdenite ore might be found by this means. It must be confessed however, that the whole occurrence appears to hinge upon the possibility of working the deposit *as a whole*, inasmuch as there appears to be no concentration of the ore within definite boundaries, such as within a pipe, a vein, or a large spheroidal segregation.

5. *Wildblood's Claim.*—P.M.A. 1, of 20 acres. Portion 10, W. Stanley's C.L. of 960 acres, Parish Sandy Creek, County Hardinge, and adjoining Macpherson's Lease (P.M.L. 1) to the west. The road from Booroolong to Balderslie passes through the Authority.

According to Mr. A. E. Bennett, this area was taken up by Messrs. McWilliams, Bennett, and Macpherson.

The country is of siliceous granite within which large masses of aplite and pegmatitic granite occur, and throughout which molybdenite flakes are scattered freely. Just between the Booroolong-road and the creek draining the locality, a large outcrop of drusy and pegmatitic granite was found. It exceeded 100 feet in length and 30 feet in width, and numerous molybdenite flakes were found therein by the prospectors. A large shallow pit was made in this outcrop, but at the time of my examination in 1915 this excavation was nearly full of water. It may have been 10 or 12 feet in depth. A large heap of low-grade molybdenite ore was lying alongside the pit.

The deposit is deserving, perhaps, of further prospecting in the expectation of a large segregation or "bung" of rich ore being found. The deposit is very large, without definite shape, and there are no surface indications of concentration within pipes, veins, or "bungs" at a depth. On the other hand, the outcrop suggests that the deposit is a type of granite which contains a very low content of molybdenite, scattered at random as flakes throughout the mass.

In prospecting it might be advisable to sink a vertical shaft to a depth not greater than 50 feet, and thence to crosscut for distances, at right angles to each other, of 25 feet in each direction from the bottom of the shaft. Should any pipe, vein, or shoot of ore be revealed by this speculative prospecting, it should be followed. Should, however, no results be obtained more favourable from a commercial point of view than those already shown by the pit working, then the deposit might be considered sufficiently tested, unless, indeed, the mass be treated as a whole by quarrying and treatment on a wholesale scale.

6. *Snape's Authorities.*—P. J. Snape took up two Authorities to Enter in 1915, one in E. M. Mulligan's C.L. of 1993 acres, Portion 14, and one in Portions 11 and 12 on F. W. B. H. Stanley's A.C.P. and C.L., Parish Sandy Creek, County Hardinge.

Of these the former contains molybdenite flakes in granite near quartz-porphyry, while within the latter Authority the molybdenite occurrence is similar to that shown in the authorities and leases in the vicinity.

7. *Stanley's Authority.*—This Authority to Enter was taken up on W. Stanley's C.L. of 960 acres, Portion 10, Parish Sandy Creek, County Hardinge

The occurrence is somewhat similar to those lying about a mile to the south-west and south-east, and which have been described above.

Botobolar Deposits. Molybdenite flakes in granite.

Boundary Creek. *See* Rocky River.

Bow Creek Mines. *See* Deepwater.

Boyd's Block. *See* Yetholme.

Boyd's Molybdenite Yetholme Mines. No Liability. *See* Yetholme.

Brewongle.

Nine miles east of Bathurst. Molybdenite in flakes, set in white quartz, occurring in the Bathurst granite. The occurrence was only of scientific interest.

This deposit was shown to me in 1896 by the late Mr. William Pascoe, of Bathurst.

Broken Hill.

Wulfenite, with silver and lead ores. Quoted from "Mineral Resources," 1901, p. 306, by E. F. Pittman.

Bruce's Hill. *See* Holbrook.

Buckridge's Block. *See* Yetholme.

Bullin Flat.

Near Goulburn. Quoted from "Mineral Resources," 1911, by E. F. Pittman, under Molybdenite.

Bundar. *See* Mole Tableland.

Bungulla. *See* Tenterfield.

Burrowa. *See* Appendix.

Butcher's Creek. *See* Nambucca.

Cahill's Claim. *See* Kingsgate.

Capertee.

Twenty-two miles north of Wallerawang. Quoted from "Mineral Resources," 1901, p. 306, by E. F. Pittman.

Captain's Flat. *See* Goulburn.

Carcoar.

Information supplied by Mr. G. W. Card, Curator of Mining Museum; four specimens forwarded.

Carrai Deposits.

The accompanying notes have been prepared from information supplied by my colleague, Mr. M. Morrison.

The molybdenite prospected by the Australian Exploration Company, Ltd., occurs on M.L. 15, Parish Warne, County Dudley, on the rugged eastern falls of the Carrai Tableland, 65 miles by road in a direction south-easterly from Armidale. The molybdenite occurs in a siliceous granite near its intrusive contact with claystones and other altered sediments of Permo-Carboniferous age.

A small prospecting hole about 10 feet long, 8 feet wide and 6 feet deep, had been made in ore consisting of greisen and quartz arising from an alteration of the granite.

Iron pyrites, copper pyrites, and zinc blende, were associated with the molybdenite. Alluvial tinstone was found in stream drift overlying the deposit under consideration.

It is stated that 10 cwt. of ore, containing from 5 to 7 per cent. molybdenite, was sent to Sydney from this spot for treatment.

Cathcart. *See* Tantawanglo.

Cheviot Station. *See* Drake.

Chorley's Claims. *See* Bungulla under Tenterfield.

Clarke's Claims. *See* Tantawanglo.

Cleaver's and Hennessy's Claims. *See* Goulburn.

Cleveland Bay.

Quoted from "Minerals of New South Wales," 1888, p. 71, by A. Liversidge.

Conrad Lode. *See* Tingha.

Cornwall (New) Lode. *See* Elsmore under Tingha.

Coolamanger. *See* Rocky River.

Cooper's Claim, No. 1. *See* Bolivia.

Cooper's Claim, No. 2. *See* Bolivia.

Coronation Mine. *See* Deepwater.

The Deepwater Deposits.

For the sake of uniformity in the geological description the Deepwater deposits are considered to be those which occur to the east of Deepwater, while the group lying to the north and north-west of Deepwater and associated with the Bolivia and Slippery Creek granites are considered under the head of Bolivia deposits.

They may be divided into two types :—

1. Those consisting of pipes in a coarse granular granite near its intrusive contact with quartz-felspar porphyry and altered claystone.

2. Those consisting of quartz greisen and pegmatite veins in a coarse granite near their contact with altered claystone or other rock types.

In the first type the granite is not highly siliceous; it forms low rolling country which is flanked by high porphyry hills, and it has intruded the associated rocks in broad swelling curves, the junction lines being clear and

distinct. It is, in fact, a true molybdenite granite, such as is that also of Slippery Creek, Bolivia, a few miles to the north, as well as that of Kingsgate, a short distance to the south.

The second type occurs in granite of very siliceous nature forming wild and high plateau country near the Main Divide, a few miles east of Bow Creek mines, and at the head of the Ten Mile and other Deepwater River heads. This granite plateau forms rough escarpments to the main New England plateau, upon which the Bow Creek deposits occur.

This granite would be classed better as a wolfram than a molybdenite type. As might be expected, there are overlappings of characters in these granites inasmuch as they all belong to one period of intrusion, thus the Bow Creek granite has a sandy phase at its margin in one small place, and this is indicative of wolfram. Kingsgate also, in Lancaster's leases, possesses a rare development locally of aplite or allied material at the margin of the main broad curve of intrusion. This also suggests a slight overlapping of the molybdenite and tin-wolfram granites, and is suggestive of a minor wolfram and tin content at or near that spot.

In the description of the Bolivia deposits there may be found a general description of the mineral associations and characteristics of the Bow Creek deposits of Deepwater. Both these molybdenite granites appear to be intimately related, and it is probable that they are directly connected below the plateau surface.

1. *The Allies Mine*, or the Allies Molybdenite and Bismuth Mines.—P.M.A. 1, of 20 acres, and P.M.A. 3, of 20 acres, on Cadell's and Smith's private land, Parish Deepwater, County Gough, and about 6 miles east of Deepwater, just beyond Manbundi Mountain.

The general geological relations of the Allies and Bow Creek Mines are shown on Plate IX.

A pipe within P.M.A. 1 was prospected about ten or twelve years ago by a Mr. Nobbs, of Sydney, together with some Deepwater residents. The original prospectors appeared not to understand the difficulties and uncertainties associated with molybdenite pipe-mining, and after a period of 15 months or thereabouts they appeared either to have lost the deposit or to have found it unremunerative. It then lay idle for a period not exceeding a year, when the Authority was cancelled. At a date considerably later it was secured by Mr. E. A. Baker, who took up P.M.A. 3, also of 20 acres, to protect the continuation of the pipe as it dipped away from P.M.A. 1 into Mr. Smith's ground.

The accompanying sketch geological map of P.M.A. 1 and P.M.A. 3 illustrates the general occurrence of the pipe.

The deposit is what may be termed a granite or pegmatitic pipe, the rock in many places consisting of a paste or base of glassy quartz, in which are scattered felspar crystals either isolated or in aggregates. Crystallised and massive quartz occurs as a sort of core to the pipe, especially on the so-called hanging-wall portion. It outcropped on the edge of P.M.A. 1 (Pl. IX) and was worked by means of a shallow open cut. Beyond the limits of this pit or cut it was followed in a southerly direction into P.M.A. 3. The dip was very flat for a distance of 120 feet as measured along the workings. Beyond this it dipped at an angle of 45 degrees, the total length worked being about 150 feet from the outcrop, but the total vertical depth reached not exceeding 50 feet. A vertical shaft was sunk within P.M.A. 3 to a depth of 37 feet to connect the surface directly with the lower workings. This shaft was sunk in claystone to a point near the pipe at which granite was struck. The

flatness of the pipe and the contact of granite and claystone is very marked, the pipe, however, being wholly within the granite, but at no place is it more than a few feet or yards from the intrusive contact.

The pipe is of variable size, in some places being about 10 feet wide and 4 or 5 feet in vertical thickness. Several flat branches have been prospected, but none of them have been followed far from the main pipe. They appear to be related definitely to small joints in the granite.

This class of pipe is very difficult to follow owing to its granite nature, and to the low molybdenite content in places. There is no reason, however, to doubt that the type is persistent with increase of depth, and in my opinion this deposit is a valuable one which is worth further development.

Treatment.—In 1915 the ore was crushed by hand rolls and sieved. The rich concentrate exceeded 90 per cent. molybdenite, and the seconds were reported to average 5 or 6 per cent. molybdenite. This was sent to Messrs. Beil and Poulot, of Sydney, for treatment.

Production.—1914 : 11 tons of picked ore produced 1½ tons of molybdenite concentrate, valued at £700.

1915 : 32½ tons of picked ore produced 3½ tons concentrate valued at £1,657.

2. *The Bow Creek Molybdenite Mines, No Liability.*—P.M.A. 2, of 20 acres, Parish Deepwater, County Gough, about 6 miles east of Deepwater Railway Station.

The country is gently undulating in nature, and a good bush track connects it and the neighbouring Allies Mine (Pl. IX), with the main Northern Railway at Deepwater.

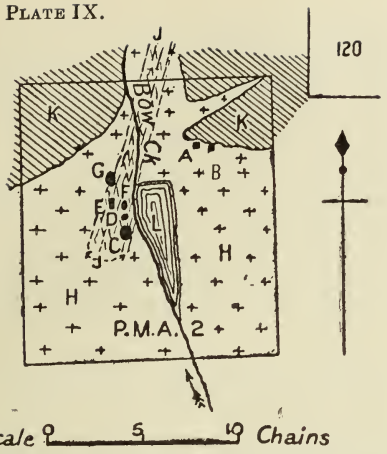
The molybdenite occurs in pipes of quartz and pegmatite within coarse granite near its intrusite contact with claystone. One group of the deposits found in the lease occurs in a wide siliceous zone caused by the formation of innumerable small discontinuous quartz veins, the granite between the veins being silicified.

The pipes outcrop alongside of Bow Creek, from which an abundant supply of water is available at most times.

In 1902 the Writer inspected this spot in company with Mr. G. V. Collins, of Maitland. Several outcrops of quartz, quartzose granite, and pegmatite, were inspected. These had been prospected to a depth of a few feet. Through the large siliceous pipe, known as No. 2, on the left-hand bank of the creek, large and beautiful crystals of molybdenite were scattered as rosettes and hexagons. These crystals in certain instances were as much as 2 or 2½ inches in diameter and varied from ¼ to 2 inches in depth or length. Such a prospect was most encouraging both from a prospector's and a metallurgist's point of view. Owing, however, to an almost complete ignorance of molybdenite or bismuth pipes, and being faced with the added difficulty of following a granite pipe, the prospectors expended money and time needlessly in digging the surface about instead of following the pipe. Another difficulty also to be faced was their inability to distinguish branches and droppers from the main pipe. They were advised to follow the quartz, or granite, containing molybdenite wherever it might lead them. These original prospectors, however, were possessed of the idea that, to be of any real value to them the deposit must be of the nature of a definite fissure vein, hence their disappointment and abandonment of the property.

In 1913 the area was secured by Mr. E. A. Baker, as P.M.A. 2 of 20 acres, about the same time that he had secured P.M.A. 1 covering the Allies Mine nearly 2 miles to the south. Mr. Baker employed fourteen men for a few

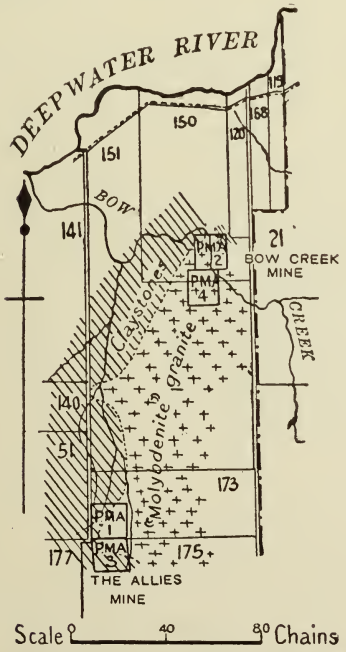
PLATE IX.



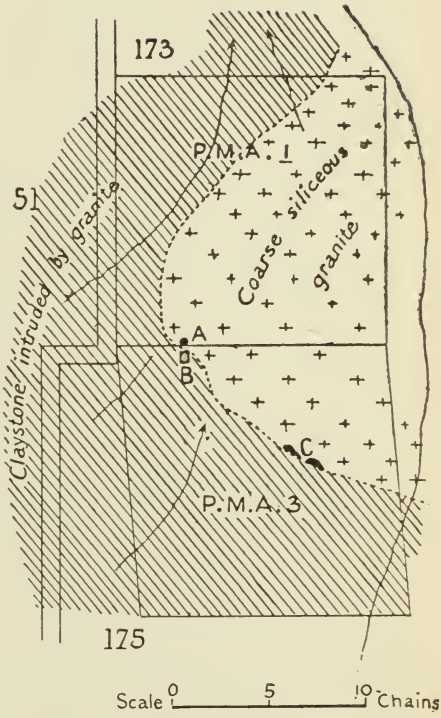
Sketch map of P.M.A. 2, Parish of Deepwater, County of Gough.
The Bow Creek Molybdenite Mines, No Liability.

A—No. 1 Shaft, 80 feet deep
B—Shallow Shaft
} In coarse siliceous granite near claystone contact.

C—Old shallow workings in quartz granite pipe.
D E F G—Shallow workings in pipes.
H—Coarse siliceous granite.
J—Line of quartz veins with intersecting veins.
K—Claystone.
L—Dam.



Plan of locality Bow Creek and Allies Mines, Parish of Deepwater, County of Gough, P.M.A. 1, 2, 3, and 4.



Sketch map of P.M.A. 1 and P.M.A. 3, Parish of Deepwater, County of Gough.

A—Outcrop of pegmatite pipe in granite.
B—Vertical shaft sunk through claystone to intersect pipe in granite.
C—Greisen containing molybdenite and bismuth at intrusive granite contact.

months upon nine distinct outcrops, several of which, however, may be branches of No. 2 pipe. Machinery for mining and treatment of the ore was purchased to the extent of £20 and 70 tons of rich ore were raised but not treated. An early proposal was made to crush with a rockbreaker and with rolls, the crushed material to be sieved and screened, and the undersize to be treated by some form of oil flotation.

At the close of 1913, on the right-hand bank of the creek (Pl. IX) No. 1 pipe was prospected afresh and was 80 feet deep in 1915.

During the first six months of the year 1914 the Bow Creek Company raised 65 tons of ore, from which 1 ton 12 cwt. 2 qrs. of molybdenite was obtained, valued at £735. Three shafts had been sunk and a plant had been erected at a cost of about £800.

The mine was closed in August, 1914. The following notes dealing with the additional history of the mine have been supplied by Mr. A. D. Pedley, of Sydney.

"The Bow Creek Molybdenite Mining Company had a capital of £1,800, and further capital to the extent of £360 was subscribed about November, 1914. Very little has been developed since that date of a more promising nature. Molybdenite certainly occurs in the pipes, but the costs of mining and treatment are very great, indeed, the actual costs of mining and treatment would astonish the ordinary prospector." According to Mr. Pedley, the actual costs of mining at Bow Creek are about £3 a crude ton (*see* pp. 45, 47, in this connection).

On the accompanying sketch map (Pl. IX) of Bow Creek only the more important workings are indicated. The granite to the south of the shafts A and B is coarse, while that to the north is fine in texture. This suggests the presence of wolfram.

No. A is known as No. 1 Shaft by the miners. It has been sunk almost vertically on the course of the pipe, to a depth of 35 feet, thence for a distance of 15 feet or thereabouts, the slope of the pipe was almost negligible, thence for a depth of 30 feet perhaps the slope is steep. The general pitch of the pipe is to the north and in the direction of the granite and claystone contact. At a depth of 35 feet the pipe appears to branch or split, one arm dipping steeply to the south, the other to the north. This branch had been worked for a depth of 10 feet below the 35-ft. level during September, 1915. The material of the branch consisted of quartz with molybdenite, whereas the deposit as worked from the surface to a depth of 35 feet consisted of a paste of glassy quartz studded with whitish or grey felspar, and within which large irregular patches of quartz occurred, both massive white and crystallised, containing molybdenite and bismuth. This pipe is variable in size, being 10 feet across in places. During 1915 the walls of the pipe branches were coated so thickly with smoke and mud that it was impossible to discern much beyond the mere form of the pipe branches. It was thus impossible also to suggest any information of assistance beyond noting the fact that the lowest workings were in pipe material of a sort, and that a couple of large quartz scabs were seen on the smoky walls.

At the lowest point reached there were signs of a local constriction in the pipe, and a lack of definiteness about the pipe material itself. The general appearance of the lowest face is indicated in Fig. 7. Instead of a cylindrical mass of ore and gangue, the face consisted of bands and threads of discoloured granite containing molybdenite, the whole suggestive of action along joints.

This may be only a local phase, and at a depth slightly greater the pipe may be expected to be found as strongly as ever, unless this branch is merely a dropper.

The workings on the western side of the creek consist of open cuts, pits, and shallow shafts, on granite and quartz pipes, all close together and all arranged along a hard zone of altered granite containing innumerable but small and discontinuous quartz veins (Pl. IX).

No. 2 pipe, shown on the map as C, and from the outcrop of which splendid specimens were obtained in 1902, is related to a strong joint plane dipping in a northerly direction at an angle of about 1 in 3. The joint or plane, where seen, had a footwall of silicified granite, while above it lay a mass of crystalline and cavernous quartz. The pipe appears to occur as a local thickening or shoot within this plane in two directions but thickening at right angles to the pitch of the plane.

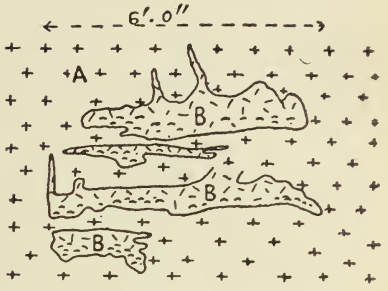


Fig. 7.

Sketch section of pipe at bottom of No. 1 Shaft P.M.A. 2, Parish of Deepwater, County of Gough.

A—Coarse siliceous granite.

B—Felspars in glassy quartz paste containing abundant flakes of molybdenite. Chlorite and iron oxide is developed in these rib-like masses.

The pipe was worked first as an open cut, thence it was observed to dip almost due west at a low angle. Beyond that (almost 50 feet) from the outcrop it has not been traced definitely owing to various leaders of molybdenite ore following the main joint or plane under consideration. The pipe may dip north as suggested by the expansion of the quartz in that direction.

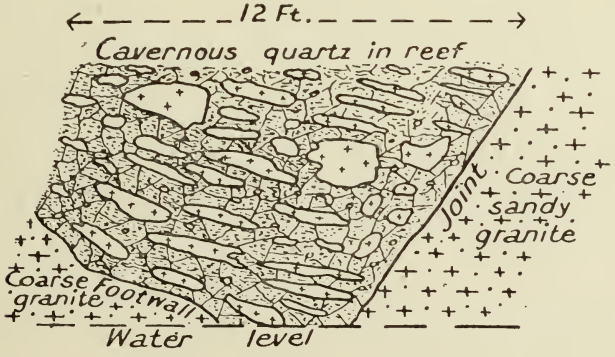


Fig. 7 (*a*).

Sketch section of face of No. 2 Pipe, Bow Creek, from measurements.

The coarse fragments of the breccia consist of silicified granite, while the interstitial matter is impure quartz. The country is granite.

Fig. 7 (*a*) is a sketch section of the northern face from measurements taken by Mr. A. E. Finch and myself. The large fragments, suggestive of the material of a breccia, are portions of granite much silicified and otherwise

altered in place, the material between the fragments is continuous in all directions and consists of quartz and impure silica, the whole forming a body of incomplete replacement from a set of interlacing quartz veins. Very little molybdenite was seen in this breccia of replacement.

Treatment Plant.—Treatment of the ore was conducted in 1915 by crushing and sieving dry. The crude ore was said to be handpicked to 5 or

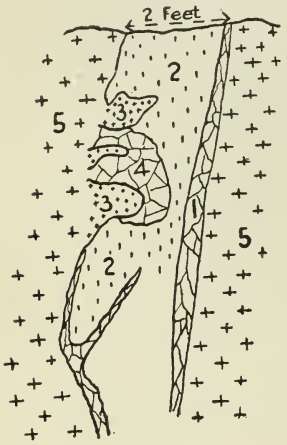


Fig. 8.

(*a*) Coronation Mine.

1. Quartz vein.
2. Molybdenite crystals in crystalline felspar.
3. Granite veins or segregations.
4. Quartz, with small percentage of felspar.
5. Granite country.

A shaft 32 feet deep has been sunk on the reef. The country is a coarse acid granite, and closely associated with the reef is a huge barren quartz vein. The occurrence was shown to the author in 1902, by Mr. F. W. Thompson, of Deepwater.

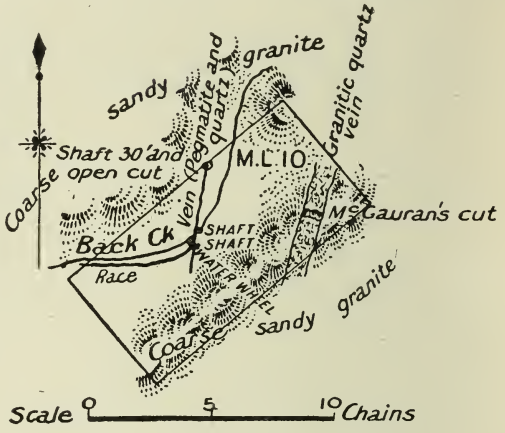


Fig. 8.

(*b*) A sketch geological map of M.L. 10, Old Coronation Mine, Parish Parkes, County Gough.

7 per cent. molybdenite, and then fed by hand into a small jawbreaker, in which it was broken to half-an-inch gauge. Thence it was crushed to $\frac{1}{16}$th inch gauge by rolls, whence it passed over a shaking screen with 16 holes punched to the square inch; the oversize being rerolled to $\frac{1}{32}$ inch gauge. The undersize from the rolls was sent to Sydney to be treated at Mr. G. E. Baker's treatment plant at Gas-lane, Sydney. The oversize was stated to contain 80 per cent. molybdenite, together with a considerable amount of gangue in the form of grains and fragments owing to the uneven wearing of the rolls. This concentrate was coarse in texture and was put through rolls set close together. The oversize from this treatment was a concentrate containing from 90 to 92 per cent. molybdenite, the undersize being also rich in molybdenite.

In my opinion this is a valuable deposit, but skill and care would be necessary to follow the ore.

3. *Coronation Mine.*—M.L. 10 of 10 acres, Parish Parkes, County Gough, on Back Creek, near the head of the Deepwater River, upon a high rough plateau forming a western spur of the Great Divide, and about 13 miles east of Deepwater. The deposit is known also as Thompson's Claim and McGauran's Claim. The bush road from Deepwater to the foot of the plateau is good, but beyond that it is very poor.

The molybdenite is contained in a pegmatite vein of peculiar nature which traverses a granite coarse and granular in texture and very siliceous in nature. It comes under the head of wolfram-tin granites.

The vein has a strike about N. 10° E., and a dip almost vertical. It is peculiar in that its central portion consists mainly of massive felspar, containing molybdenite and a minor proportion of quartz, while its extensions north and south of this central portion are narrower, and consist mainly of a flinty quartz paste containing infrequent and small crystals of felspar. That portion of the vein which was opened in 1906 was about 2 feet 6 inches in width, while alongside the felspathic pegmatite a small vein of quartz averaging about 4 inches in width occurred carrying molybdenite. The bulk of the molybdenite won was found in the pegmatite of the central portion. The accompanying figures illustrate the occurrence.

A shaft 32 feet in depth was sunk on the vein about the year 1902 by Mr. F. W. Thompson, of Deepwater. Mr. Thompson also sank a few other holes on the vein. Rich molybdenite specimens were found in the felspar, but as the holes were sunk in the bed of a narrow and rocky watercourse containing a permanent flow of water, mining operations were considerably hampered thereby. Mr. Thompson constructed a waterwheel and fluming to cope with the water, but the prospects of the vein did not appear to justify more prospecting, and the claim was abandoned temporarily.

Mr. John McGauran later applied for a lease of 10 acres over the area, and commenced prospecting the northern end of the vein, as also a series of large quartz veins traversing the more easterly portion of the 10-acre lease.

At the northern portion of the pegmatitic vein, on the boundary of the lease, Mr. McGauran had excavated a large plat in 1915, and had sunk a shaft below the same, the lowest point of the workings being about 30 feet below the surface. This work has proved the existence of two small quartz veins, about 4 inches each in width, and separated by 8 or 9 feet of barren granite.

Mr. McGauran has also made a wide costeaning trench, 50 feet long and from 7 to 8 feet in depth, across the group of peculiar quartz veins in the eastern portion of the lease. These veins were prospected for molybdenite and bismuth, but nothing of importance appears to have been found therein up till the present time.

A peculiarity of these large eastern veins is that they have a flinty or felsitic appearance in outcrop, whereas in reality they are composed of a silica paste in which small and scattered felspars occur, varying in amount from 5 to 25 per cent. of the whole mass.

To sum up, the eastern veins have not been proved to contain molybdenite while the western or pegmatitic vein is small, even in its central portion, and it contracts markedly in directions north and south from the centre. The molybdenite content, as shown by prospecting, is moderate in amount, and miners, with primitive appliances only, would find it almost impossible to work because of the heavy water. In any case, it is at present only a prospecting claim, as are also so many others of the New South Wales molybdenite deposits.

4. *Ford and Barnett.*—Authorities to Enter 5 acres on Portions 155 and 156, Parish Deepwater, County Gough. Molybdenite flakes.

5. *Rummery's Claim.*—M.L. 7 of 10 acres and M.L. 8 of 2 acres within Portion 141 of 60 acres, Parish Parkes, County Gough, and about 12 miles

east of Deepwater by road, the last 1½ miles being rough and steep, rising to a high spur of the Main Divide. The areas are leased for wolfram, bismuth and molybdenite.

This area is evidently that referred to as Ding-Dong in the report by Mr. J. E. Carne.* and quoted by him from a report by Mr. C. S. Wilkinson† on that area. The extract from the original report is here reproduced :—

> "At Ding-Dong, near the junction of the slate formation and granite, the latter, which is coarse-grained granite, contains irregular-shaped masses of greisen rock, composed of quartz and mica in varying proportions. These masses appear to have been formed by segregation, and the tin-ore occurs disseminated, though chiefly in bunches. I also saw small tin veins in the altered slates. In portion 141 a shaft has been sunk to a depth of 30 feet, following down a greisen lode, which is from 2 to 3 feet wide. A joint runs through the centre of it, dipping S.30°E. at 57°, and at right angles to this are other joints across the lode, some of them being open with empty spaces 4 inches wide in places. The tin ore is in patches, and scattered crystals in a shoot 10 feet by 2 feet, following nearly the line of joint. It would seem as if the tin ore had crystallised from a solution or vapour, which penetrated the rock from the joint fissure. Five of these masses of greisen containing tin, some with quartz veins, have been prospected, and there are, no doubt others not yet opened. Wolfram is, in places, associated with the tin. A gully discharges from the hill in which these lodes occur, and at the foot of the hill it opens on to an alluvial flat, in which there are probably payable deposits of stream tin. Some small tin lodes have also been found in the range near Back Creek, about 3 miles farther east."

Since Mr. Wilkinson's report was made, it has been ascertained that the tin deposits in Portion 141 are very poor. The area has been prospected for wolfram and molybdenite since that date.

According to Mr. J. R. Rummery, the area was reworked about ten years ago for wolfram and bismuth by Cassidy and party. From a vein found in M.L. 7, this party is said to have won 3½ tons of wolfram and bismuth. Mr. Rummery took up M.L. 7 and 8 about eight years ago. In 1913 he won about £170 worth of wolfram and bismuth, with a little molybdenite.

The minerals wolfram, bismuth, and molybdenite, occur in narrow veins of quartz traversing a mass of greisen, fine in texture, and lying between a coarse, sandy granite and a mass of altered claystone (Fig. 9). The granite is more siliceous than the typical molybdenite granites of Deepwater, Kingsgate and Whipstick. This is suggested also by the vegetation of the area.

The greisen also, which lies between the granite proper and the included claystone, is suggestive—at least in New England—of a wolfram granite, and does not suggest molybdenite deposits of importance.

In places the greisen appears to be an altered granite. In other places it is very siliceous and somewhat similar to a granular quartz, with fine and scattered flakes of mica. The greisen is traversed by small true veins of quartz, having a strike almost north-north-east and a slight underlie to the east. The western vein has been prospected for a distance approximately of 150 yards, and the eastern one a distance of 100 yards. The original veins were narrow, and may be recognised by the shape and their filling of true quartz, but the greisen has been altered for varying distances from the

* The Tin Mining Industry. Mineral Resources, No. 14, 1911, p. 293.
† Annual Report, 1883, p. 151.

original fissures or joints to an impure form of quartz or silica. This gives the appearance of irregular fissures much larger than the true veins are in reality. In places the quartz is dense and of tough nature, but in others, especially where the wolfram, bismuth and molybdenite occurs, it is softer or more "kindly," according to the miners, and it is broken up by "floors." Vughs also are found in the deposits.

The width of the western vein, as worked, varies from 18 inches to 5 feet. Cassidy and party worked the northern portion by means of open cut to a depth of 25 feet, while Mr. Rummery has prospected the southern portion of this vein to depths varying from 15 to 20 feet. The eastern vein has been prospected also by means of shallow shafts and holes to depths varying from 5 to 20 feet.

Molybdenite is quite subordinate in amount to the wolfram, and it occurs as small flakes in the quartz, associated with wolfram and bismuth.

These veins are those which might be expected to be worked by a small party of miners, who could concentrate the ore to a certain grade by means of inexpensive machinery, the ore thus concentrated being sent to a Customs plant for treatment. The narrowness of the veins and the moderate percentage only of minerals under consideration indicate the inadvisability either of erecting an expensive plant or of the formation of a company beyond a small one of actual prospectors.

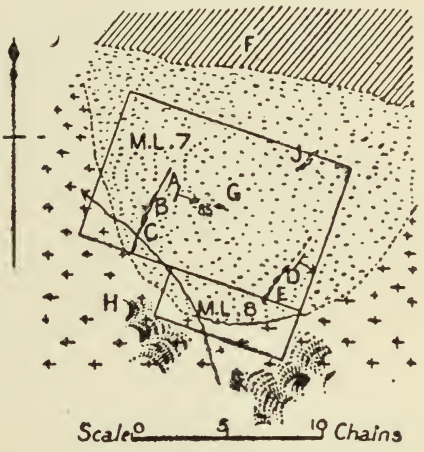


Fig. 9.

Parish of Parkes, County of Gough.

A—Old workings 25 feet deep.
B and C—Workings in vein 2 feet to 3 feet wide; quartz veins containing wolfram and molybdenite.
D—Shaft 30 feet deep in vein of wolfram, bismuth, and mica.
E—Shafts and holes.
F—Claystone.
G—Greisen.
H—Coarse siliceous granite.
J—Small veins of quartz containing wolfram.

Delegate.

The Wallendibby Mine.—The accompanying notes on the molybdenite deposit reported from this district have been compiled from information supplied by Mr. Warden Gunn, of Cooma, and from P.B. Papers 15/4891, Mines.

Mr. H. J. Gallop was prospecting an area of 40 acres at Black Jack Mountain, Meranbego, Parish Merrumbulo, County Wellesley. A shaft had been commenced on some stone containing molybdenite, and an application was made for aid from the Prospecting Vote to sink to a depth of 50 feet.

In July, 1916, the shaft had been sunk to a depth of 32 feet.

The deposit had been prospected previously by Mr. C. Fokes, who sank a shaft to a depth of 27 feet. Mr. D. Milne, Inspector of Mines, at a later date, recommended aid to be granted to Mr. Gallop to sink at another spot. According to Mr. Milne, the molybdenite occurs as flakes scattered irregularly throughout the granite.

DIEHARD.

P. McCanna holds 20 acres within Portion 4, Parish Diehard, County Gough, as an Authority to Enter. Occurrence is molybdenite in granite.

Information supplied by Mr. Warden Perry.

DING DONG MINE. *See* Deepwater.

DODGER MINE. *See* Maurer's Claim, under Yarrow Creek, under Kingsgate.

DONALDSON'S CLAIMS. *See* Bungulla, under Tenterfield.

DRAKE.

Said to occur as flakes in sandy granitic rock on Cheviot Station, north-east of Drake. *See* Appendix.

Information supplied by Mr. Warden Perry.

DUCKMALOI RIVER. *See* Oberon.

DWYER'S (D.) CLAIM. *See* Oberon.

EDEN.

"On the face of the cliff on the north side of the township are numerous quartz veins, which reticulate the beds, and these are charged, as similar veins are near Pambula, in the vicinity of igneous disturbance, with molybdenite."* The rocks containing the molybdenite appear to be red slate or sandstone from the description.

EDWARDS' (RUSS AND EDWARDS) CLAIM. *See* Moonbi.

ELSMORE. *See* Tingha.

ELSMORE TIN SLUICING COMPANY. *See* Elsmore, under Tingha.

FEARNSIDE AND FLETCHER'S CLAIM. *See* Bolivia.

FIELD'S AND GARRARD'S BLOCKS. *See* Yetholme.

FINUCANE'S REEF. *See* Black Range.

FLINT'S MOLYBDENITE VEIN. *See* Wilson's Downfall.

FORD AND BARNETT'S CLAIM. *See* Glen Elgin.

FORDHAM'S VEIN. *See* Wilson's Downfall.

FORTY. *See* Kingsgate.

FORTY NORTH. *See* Kingsgate.

FORTY SOUTH. *See* Kingsgate.

FRENCH'S MINE. *See* Burrowa.

FULTON'S (A. E.) CLAIMS. *See* Tantawanglo.

GALLOP'S CLAIM. *See* Delegate.

GEMALLA. *See* Yetholme.

GEORGE'S CREEK. *See* Laura Creek.

GIANT BLOW (Yates'). *See* Kingsgate.

GIANT BLOW (Speckhardt and others). *See* Kingsgate.

GLEESON'S CLAIM. *See* Black Range.

GLEN CREEK. *See* Mole Tableland.

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* W. B. Clarke, Southern Gold-fields, p. 194, &c.

The Glen Eden Deposits.

These comprise M.L. 1, P.M.A. 5 and P.M.A. 6 on a travelling stock reserve, and Portion 88, E. Newsome's Freehold, Hogue's Creek, Parish Boyd, County Gough, about 12 miles northerly from Glen Innes, near the main road from Glen Innes to Tenterfield.

The subject deposits were worked mainly for wolfram, but tinstone, bismuth, and molybdenite occur with the wolfram.

In the year 1883 these deposits were examined by Mr. C. S. Wilkinson, a copy of whose report* is here reproduced.

> About 12 miles north from Glen Innes, and about one mile east of the Tenterfield Road, several bismuth and tin-bearing quartz veins have been discovered. These occur in a different manner from those of Kingsgate. They form irregular veins and masses of quartz, traversing a fine-grained micaceous felsitic rock, which is surrounded by altered sedimentary rocks. In one place this rock for a length of about 100 yards and a width of 15 yards is traversed by a network of quartz veins. A small hole has been sunk here, and the stone taken from it contains bismuth ores, cassiterite, molybdenite, arsenical iron, and wolfram. In another place, about 100 yards from that last-named, a mass of hard crystalline quartz, in size at the surface about 40 feet by 20 feet, has been opened for a few feet in depth. It contains bismuth and tin ores, together with a large quantity of wolfram.

The accompanying notes on the geology and history of this locality have been taken from a report† by Mr. J. E. Carne, Assistant Government Geologist :—

> Prospected as early as 1883 for wolfram, tin, and bismuth, and at a later date for wolfram by C. S. McGlew. A quantity of wolfram was raised by E. J. Newsome in 1910, valued at £700.‡
>
> Reopened in January, 1910, by Sir Albert Gould and others, under the name of Glen Eden Mine, and a crushing and concentrating plant erected on P.M.A. 5. . . . .
>
> At this site masses and veins of quartz traverse quartz-porphyry near junctions of sedimentary rocks. Greisen is also developed on the margins of the porphyry. Massive quartz, with vugs lined with large crystals, occurs prominently in places. The quartzose lode-rock, however, partakes more of the character of the Torrington ore-rock, and will prove to be intrusive.
>
> The metallic minerals—wolfram, molybdenite, and bismuth—are associated with the quartz and quartzose rocks, whilst cassiterite occurs in the greisen in well-developed crystals.
>
> Wolfram occurs in irregular, isolated bunches, principally in thin parallel plates in quartz, but occasionally in the form of solid slugs. Some of the quartz masses are vertical, others dip flatly. At shallow depths others pinch out in the porphyry. The isolated character of the ore bunches, unfortunately, necessitates excessive dead-work in the blanks.
>
> So far, mining has taken the form of open-cutting and trenching for the most part, wherever ore makes occurred. Wolfram is visible over a considerable area, and the question to be decided is whether mining

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* Annual Report, 1883, p. 154.

† The Tungsten-Mining Industry in New South Wales. Mineral Resources, No. 15, 1911, p. 57.

‡ Annual Report, 1915, p. 57.

on a large scale, by quarrying and bulk treatment, can be profitably maintained. It would, therefore, be wise to use the existing treatment plant to this end, by direct experiment with a given quantity from the most favourable open cuts.

Hitherto the practice has been to follow the small rich bunches, which may remunerate working miners with primitive appliances whilst values are high, but which would certainly prove unprofitable to a Company.

Since the present holders took possession, 200 tons of hand-picked and dressed ore were crushed and concentrated for a return of 7 tons of concentrates, averaging about 64 per cent. of tungstic oxide.

Bismuth is present to the extent of 5 per cent. in one parcel of "seconds" assayed, but the average in the total concentrates is not commercially regarded. Molybdenite is also insignificant. Cassiterite is prominent in one small vein, which could be profitably extracted so far as exposed, but its persistence is unproven.

In 1911 W. J. Gould and J. Newsome obtained 2½ tons of wolfram concentrates, estimated at £256.*

At Glen Eden, in the Glen Innes Division, W. J. Gould and party raised 193 tons of stone, which yielded 3½ tons of concentrates, valued at about £290.†

Early in 1913 the Glen Eden Mine was closed, but since that period James Symes has taken up M.L. 1, about 31 acres in area, on the travelling stock route. Fred Parker also secured 15 acres alongside M.L. 1, including P.M.A. 6, while Jeffery Newsome secured P.M.A. 5, of 20 acres, to work for molybdenite and other minerals.

To these important notes by Mr. C. S. Wilkinson and Mr. J. E. Carne, the following may be added as a result of a visit by the Writer in the beginning of 1916.

At Glen Eden a mass of quartz and felspar porphyry, extremely siliceous in nature, has been invaded in a general north-north-west direction by a network of quartz veins of variable size and length. The zone thus formed exceeds 1,000 yards in length and 400 yards in width. The individual quartz veins are neither large nor long and are discontinuous. The general trend of the veins is northerly, but a great number cross those which are arranged in this main direction. The porphyry between the veins exhibits all gradations, from a mere clouding of the felspars and the matrix, to a complete replacement by greisen or quartz. Quartz with tinstone, wolfram, and molybdenite crystals appears to be the final stage of replacement.

The most noticeable feature, from the geological viewpoint, in connection with this molybdenite deposit, is the absence of granite outcrops, of siliceous nature, in the immediate vicinity. Sandy granites, however, carrying tin and molybdenite deposits, occur about 2 miles to the east, or north-east, towards Bald Nob, in Parish Bloxsome, and it is probable that the occurrence under consideration has been due to the action of vapours, expelled from the upper portion of a sandy granite, which lies buried only a slight distance below the zone of alteration under consideration.

Baker's Hill Deposit.—M.L. 1, 31 acres, on travelling stock reserve, Parish Boyd, County Gough. Prospected by Messrs. Baker and Chalmers in 1916. The molybdenite occurs as large and abundant flakes in a mass of

* Annual Report, 1911, p. 64. † *Ibid.*, 1912, p. 61.

quartz and greisen within the zone of alteration mentioned above. The outcrop which is being prospected is about 70 feet in extreme length and 30 feet in width, although it is only the more central portion of this outcrop which has been changed to impure or pure quartz and greisen. The outer portions pass away insensibly on all sides into felspar and quartz-felspar porphyry, traversed by a multitude of small quartz veins. In February, 1916, a hole had been sunk about 12 feet deep, 14 feet wide, and 14 feet long.

About the year 1912 a vertical shaft was sunk on the eastern side of the outcrop to a depth of 50 feet. Traces of molybdenite appear to have been found in the shaft, but prospecting operations were abandoned after the sinking of the shaft.

Towards the close of 1915 Messrs. Baker and Chalmers sank a hole on the same outcrop a few yards westward of the shaft. The greatest measurements of the excavation at the time of inspection (24th February, 1916) were 14 feet as depth, 14 feet as length on surface, and 12 feet at bottom, 14 feet as width at surface, and 3 feet width at base. There appeared to be a hanging wall exposed in the hole, dipping at an angle from 50 to 60 degrees to the westward. The gangue was a drusy and brittle quartz, translucent and glassy, and showing numerous bunches of mica, pieces of greisen, and silicified fragments of rock, all of which appear to be undigested fragments of felspar-porphyry.

From the prospecting hole about 10 tons of ore had been bagged and sold on a basis of 4 per cent. molybdenite. About 20 tons of stone lay on the surface, which appeared to contain from 1 to 1½ per cent. molybdenite. Abundant and beautiful crystals of molybdic ochre are found near the surface, the crystals being either flat and rayed, or occurring as abundant isolated needles of yellow colour, radiating from a central knob within the numerous small vughs in the quartz.

This lease is deserving of further prospecting. Magnificent specimens of needle ochre from this mine may be seen in the Mining Museum at Miller's Point.

The accompanying sketch map of the Glen Eden deposits illustrates the general relations between the Baker's Hill and associated claims.

Glen Eden Mines.—P.M.A. 5 and P.M.A. 6. These have been described already by Mr. Carne, as may be seen above. P.M.A. 5. contains the more eastern workings, consisting of open cuts and shallow shafts, and now worked by Mr. Fairy.

P.M.A. 6 contains the Glen Eden shaft, about 100 feet deep.

Within these three leases there is actually a great amount of wolfram, tinstone, and molybdenite. They are scattered about in a most capricious manner, and there appear to be only two methods of working them. One is to work a small rich patch, and then carry out a great deal of costly dead-work in searching for another patch, as pointed out by Mr. Carne. Another is to take any one large patch, such as that in the north-western portion of P.M.A. 6, or in the south-eastern portion of P.M.A. 5, and to work it as a large low-grade deposit of tinstone, wolfram, and molybdenite.

The method of groping in the dark for small rich patches appears to be impracticable. The grade of the ore is very low, and it is doubtful whether it would be payable to work this deposit on the wholesale scale even.

Glen Elgin Deposits.

These appear to be very small deposits of molybdenite flakes in sandy granites near their intrusive contacts with other rock types.

The accompanying notes have been supplied by Mr. Warden Perry :—

1. "*Donald McDonald* and *Lee Wing Yuen* hold 80 acres within Portions 33, 34, and 38, Parish Lewis, County Clive, under Application for Authority to Enter. About 20 miles east of Glen Innes on the Glen Elgin road.

2. "*Deposits on Portion* 8, Parish Lewis, a little nearer Glen Elgin than the above area, have been worked also, but have been abandoned temporarily.

3. "*T. O'Keefe* has held an area on Portion 2, Parish Farnell, County of Clive, east of Deepwater, under Authority to Enter."

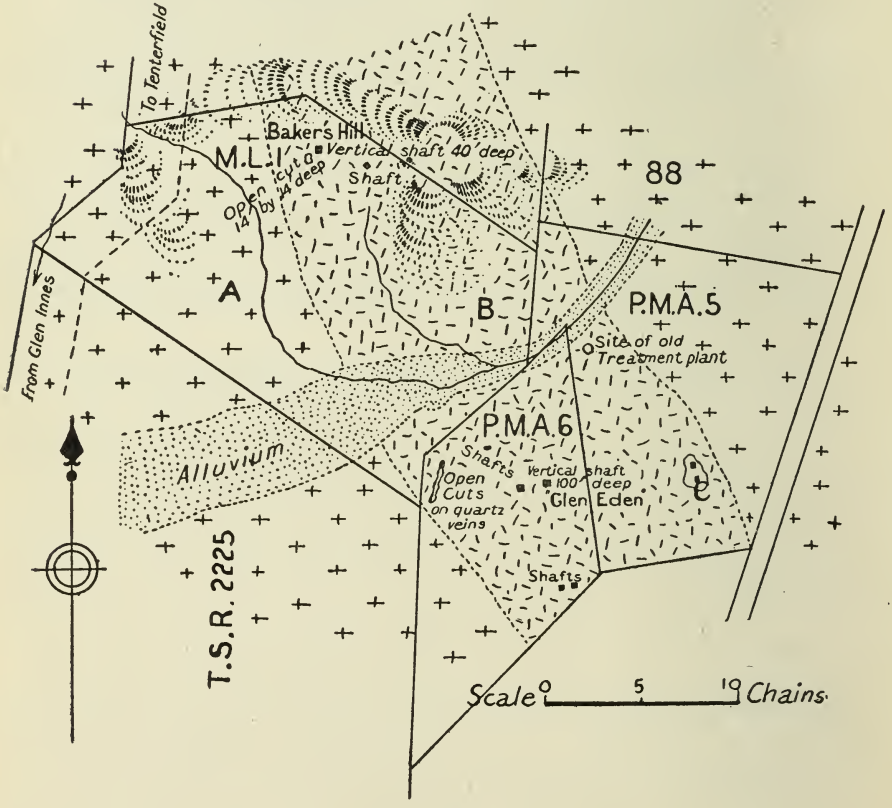

Fig. 10.

Sketch plan of Baker's Hill and Glen Eden molybdenite deposits, Parish of Boyd, County of Gough.

A—Quartz felspar porphyry.

B—Quartz felspar porphyry altered to greisen and impure silica, containing numerous quartz veins with tinstone, wolfram, and molybdenite.

C—Open cut and shafts with wolfram, tinstone, and molybdenite.

Molybdenite flakes have been found also in sandy granite at Pheasant Creek, about 22 miles north of Glen Elgin.

4. "*Pheasant Creek*, Parish Moogem, County Clive. About 20 miles north of Glen Elgin Homestead. Molybdenite in quartz in pipe veins associated with wolfram and bismuth minerals." Information from "Mineral Resources," 1901, p. 306, by E. F. Pittman.

The principal geological feature at Pheasant Creek appears to be an intrusive granite contact with quartz prophyry. Along the contact are pipes of sericite containing tinstone and allied minerals. The granite is a very sandy type and belongs to the wolfram-tin group.

Glen Innes Molybdenite and Bismuth Syndicate. *See* Kingsgate.

Gooderich Copper Mine.

"Formerly known as Buckenbah, Gordon, and Yeoval. The Gooderich Mine is situated about 4½ miles from the village of Yeoval. The ore occurs in quartz veins in granite, and consists of chalcopyrite, magnetite, and a little molybdenite and gold and silver. The mine was worked as an open quarry to a depth of 120 feet by a width of 70 feet approximately."*

Goodwin's Claim. *See* Rocky River.

Goodwin's Claim. *See* Kingsgate.

Goulburn Deposits.

This district is large but the molybdenite deposits therein appear to be insignificant. Mr. Warden Williams, of Goulburn, in a personal communication, has furnished the accompanying information.

In 1915 applications were lodged by G. W. Cleaver and C. E. Cleaver for Authorities to Enter and Search for molybdenite on Portions 211 and 213, Parish of Krawarree, County of Murray. These applications were refused as molybdenite was not reserved to the Crown in the Deeds of Grant, but search was made on this land and afterwards near Captain's Flat by the same parties.

Messrs. William and Herbert Hennessy and G. W. Cleaver made search also at a site about 8 miles west of the areas mentioned above in Parish Krawarree, in the Parish of Oranmear, the locality being known as Jerrabut Gully. In both places the searchers found molybdenite in rock formation, which they describe as "sandy granite," the lode in some instances being found with diorite walls. A shaft was sunk on Portion 213 a depth of 20 feet on a lode carrying molybdenite, but neither here nor elsewhere was it found in payable quantities. A further search was made by trenching and by sampling the loose surface rocks. . . . The lands in question are deemed worthy of systematic prospecting.

Molybdenite is also being searched for by Henry Ludwell on Crown lands situate about 3½ miles west from Towrang Railway Station. A prospecting area situate on the north-eastern corners of M.Ls. 10 and 123, Parish of Narrangarril, County of Argyle, has been marked off. Operations up to the present have only disclosed very small flakes of molybdenite.

Granite Pipe. *See* Kingsgate.

Gulf (The). *See* Mole Tableland.

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* J. E. Carne. The Copper Mining Industry. Mineral Resources, No. 6, 1908, p. 370.

Gulgong.

Small molybdenite flakes in granite said to occur 7 miles from Gulgong.

Gunn's Authority. *See* Wilson's Downfall.

Guy Fawkes Deposits.

Serpentine River locality, 40 miles easterly from Hillgrove.

The accompanying description has been taken from a report by Mr. M. Morrison, Geological Surveyor, upon these deposits.*

" The find is situated close to Back Creek in The Valley, about 40 miles easterly from Hillgrove, Parish Cunnawarra, County Clarke.

A 10-acre mineral lease, Portion M.L. 1, has been secured by Messrs. Morgan and Logan, and a 40-acre prospecting area adjoining M.L. 1, on the north, is held by J. A. Turner. Two prospecting areas of 40 acres and 45 acres respectively, are held by J. Wilson and Messrs. Keaton and party to the south of M.L. 1.

The formations in The Valley are granite and altered slates and claystones. The sedimentary rocks have been intruded by the granite, and the line of junction of the two formations is close to the left-hand bank of Back Creek.

The main granite mass is a medium-grained acid rock, composed of quartz, felspar (orthoclase), and a very little biotite. Near its contact with the sedimentary rocks it varies considerably and is mainly a fine sandstone-like granite.

The molybdenite occurs as flakes and nests in a hard crystalline quartz in the granite.

The quartz outcrops in irregularly-shaped masses extending in a north-easterly and south-westerly direction for a distance exceeding 20 chains. The masses vary in size, some being as much as 50 feet long by 25 feet across. They occur along a line having a trend of north 30° to 40° east, and are situated 1 to 5 chains from the junction of the granite and the slate. One mass which appears to be lying flat twists over and descends almost vertically in the granite along the bed of the creek. In some cases a network of thin quartz veins extends from the mass of quartz.

Up to the time of my inspection practically no work had been done on the deposits, and molybdenite was only observed where the surface cap had been removed by prospectors.

In places the molybdenite is oxidised into a yellowish mass. A sample of this ore was tested for bismuth in the Departmental laboratory, but none was detected. A sample of quartz containing molybdenite selected from a small heap, broken off the outcrop by prospectors, was also tested and yielded 2·5 per cent. of molybdenite. This must not be regarded as an average of the ore.

As no work has been done it is rather difficult to determine the exact mode of occurrence of the deposits, but I am of opinion that they are " pipes " or irregular-shaped masses of quartz descending in a more or less vertical direction in the granite. Prospecting may, however, reveal a connection between the different outcrops beneath the surface, and prove the existence of a large quartz reef, portions of which, being covered by talus from the slopes, give rise to the disconnected outcrop.

* Annual Report, 1914, p. 208.

In the event of the masses proving to be portions of a large quartz reef with molybdenite scattered through it, the present outcrop might fairly be considered as an average of its width and value at a depth. Improved values may possibly be met with where a cross-course or particular bar of country intersects the reef, but, apart from that, a reef containing insoluble metals can hardly be expected to improve in value at a depth.

The associations of these masses of quartz closely resemble those of most of the known molybdenite deposits of this State, which occur mainly as " pipes," largely composed of quartz in acid granite at or near its junction with older rocks.

Should the present deposits prove to be the outcrops of a number of separate pipe veins, the only means of exploiting such is by carefully following the molybdenite-bearing quartz down, with the prospect of striking masses or bunches of ore.

In view of the high price of molybdenite, I am of opinion that the large quartz outcrops at Back Creek present features sufficiently encouraging to warrant systematic prospecting."

Aid was granted to Keaton and Cuskelly and Logan and party in this locality. The former party do not appear to have made use of the aid granted, while Logan and party were granted aid to sink from 11 to 61 feet in depth with 100 feet of driving and cross-cutting. The aid was used only to the extent of 16 feet of sinking.

Hagen's Tribute. *See* Kingsgate.

Hammond's Claim. *See* Tantawanglo.

Haystack Mountain. *See* Mole Tableland.

Heiss' Claim. *See* Roberts and Heiss, under Rocky River.

Hilbert and Arndell. *See* Llangothlin.

Hogue's Creek. *See* Glen Eden.

Horseshoe Bend. *See* Bolivia.

Howell. *See* Tingha.

Hughes' Lode. *See* Wilson's Downfall.

Jackson and Wachman's Claim. *See* Queensgate, under Black Range under Bega.

Jerrabut Gully. *See* Goulburn.

Jessop's Claim. *See* Tantawanglo.

Jingera. *See* Whipstick.

Keaton and Cuskelly's Claim. *See* Serpentine, under Guy Fawkes.

Kempsey.

Molybdenite has been reported from the neighbourhood of Kempsey, in County Dudley. The mineral is said to occur in quartz. Reported by A. Liversidge in " Minerals of New South Wales," 1888, p. 71.

In this connection, *see* also Nambucca.

Key's (E. L.) Claim. *See* Bolivia.

Key and Parry's Claim. *See* Bolivia.

Kiandra.

Molybdenite flakes in quartz. Recorded by A. Liversidge in his " Minerals of New South Wales," 1888, p. 71.

Kiernan and Party's Claims. *See* Bolivia.

Kingsgate Deposits.

These are at once the most important molybdenite deposits at the present time in New South Wales, and the deposits which have been known the longest in this State.

The great majority of them are on Mr. W. H. Yates' freehold, the molybdenite not being reserved to the Crown.

Topography and Access.—The molybdenite and bismuth deposits of Kingsgate are situated about 20 miles east of Glen Innes. The topography of the district is moderately rugged, consisting of a plateau about 3,750 feet above sea level, roughened, on the one hand, by residuals of dense tin-granite rising to an extreme height of 5,000 feet, approximately, some miles to the south and east, and on the other hand by valleys of great depth. Near the mines themselves, however, the plateau residuals are less than 4,000 feet in height above sea level, and the Yarrow Creek, which drains the area, is sunken only from 500 to 800 feet below the general level of the plateau surface, for example, 500 feet at the upstream workings near the Old 45, and 800 feet at the northern end of Yates' workings [Pl. X (*b*)]. The slopes of the valley upon which the deposits occur are steep and rough, but the floor of the valley is of moderate width.

A good road leads across the undulating surface of the plateau from Glen Innes to the edge of the Yarrow Valley, thence down the rough valley slopes Mr. Yates has made and maintained a good private road to his own workings. A rough track only connects the workings of Sachs of Kingsgate, and the Old 45 with the edge of the plateau, although a leading spur could be utilised for the construction of a good road, apparently, at a moderate cost. The main roads and the main topographic features are illustrated in the accompanying sketch map of Kingsgate.

General Geology.—It appears fitting that the description of the general geology of the important deposits of Kingsgate should be introduced by the reproduction of a report on this area in 1883 by Mr. C. S. Wilkinson, a former Government Geologist of New South Wales. Although his report was made thirty-three years ago, and at a time when very little work had been done on these deposits, nevertheless his general remarks on the geology leave little to be added from an economic point of view. His observations on the intimate relationship existing between the marginal areas of the granites and the distribution of the molybdenite and bismuth deposits, and his generalisation therefrom that other tin, wolfram, and bismuth deposits might be expected by prospecting the margin of the great granitic masses, is a striking proof of his clear insight into the geology of the tin, wolfram, molybdenite, and bismuth deposits of New England in New South Wales. Certain points which were overlooked, apparently, by him were the nature of the granites containing the molybdenite and bismuth in this region, and the possibility of an explanation of the origin of the pipes alternative to the one supplied by him. Mr. W. H. Yates has told me that Mr. Wilkinson appeared to consider the granite as having intruded the surrounding claystones; that as a result of the cooling of the granite at a rate relatively rapid at its contact

(*a*) Vertical shaft for working No. 25 North Pipe, Yates' Property, Kingsgate.

(*b*) General view of Yarrow Creek from Yates' Blocks.

with the claystones, it developed open cavities or "pipes," by contraction upon cooling, which were filled at a subsequent period by siliceous solutions containing bismuth and molybdenite. In this idea he was supported by the knowledge of the existence of large open cavities, vughs, or caverns in the pipes themselves, some of them being as much as 10 or more feet in length and several feet in depth or height, containing immense quartz crystals with pyramid terminations projecting into the open spaces. On the other hand, a homogeneous mass in consolidating might be expected to develop a geometrical set of master joints rather than long cylindrical cavities of irregular form, or it might have been expected to develop cavities at its actual intrusive contact rather than 100 yards away from that contact. In other words, if the molybdenite had been deposited in open spaces, those spaces might have been expected to possess in the main the nature of veins or lodes.

Notes by Mr. C. S. Wilkinson :—

"The mode of occurrence of these so-called 'lodes' is very remarkable; they are *pipe-veins* or oval masses of quartz of variable thickness, descending in a more or less vertical direction in the granite, as though well-like caverns of very irregular diameter had been formed in the granite and filled with quartz and metallic minerals. Thus in one lode in the Kingsgate Company's property, two masses of quartz (which the manager, Mr. W. H. Yates, informed me were 30 feet apart at the surface), on being followed down, united and formed one large pipe-vein about 27 feet in diameter and of irregular shape, from portions of it protruding here and there into the granite. Nests or bunches of bismuth ore (native bismuth, sulphide, carbonate, and oxide of bismuth) were obtained about these protruding portions as well as through the mass of quartz; and in order to take out the vein-stone a large excavation about 60 feet by 40 feet has been made. The vein has only been sunk to a depth of 50 feet. The quartz is of a coarsely-crystalline nature, and contains, in patches, a considerable quantity of molybdenite. The metallic bismuth and sulphide occur in the solid quartz, but the carbonate and oxide lie chiefly in the joint fissures in the quartz. In places masses of native bismuth are found between crystals of quartz in the vein, and when removed the impress of the quartz crystals is well shown. . . . The largest mass of native bismuth found here weighed nearly 30 lb.

Other similar veins, but smaller, have been proved, though only for a few feet in depth; one contains much arsenical pyrites and hexagonal plates of molybdenite. An average sample of these sulphides gave an assay :—

Metallic bismuth, 2·6 per cent.

Fine gold, at the rate of 8 dwt. per ton.

Silver at the rate of 3 oz. 5 dwt. per ton.

On portion 25, about half a mile north-west from here, another large pipe-vein is being opened; near the surface it consists of a very ferruginous mass of quartz, about 13 feet by 9 feet, containing bismuth, arsenical pyrites, wolfram, and molybdenite. The screened vein-stuff is said to yield about 50 lb. of bismuth-ore per ton, which will probably be equal to about 1 per cent. of ore for the whole vein-stuff.

A sample of the ore, consisting of mixed particles of native bismuth, carbonate, sulphide, and oxide, yielded on assay:—

Metallic bismuth, 69·3 per cent.
Fine gold, at the rate of 4 oz. 1½ dwt. per ton.
Fine silver, at the rate of 57 oz. 3 dwt. per ton.

The result of assay of the ironstone from this vein was 0·6 per cent. of bismuth and no gold; and the arsenical pyrites gave only a trace of gold and bismuth, with silver at the rate of 12 oz. 5 dwt. per ton. The gold, therefore, appears to be almost entirely contained in the bismuth ore, probably in the metallic portion of it.

Several veins of a similar nature have been opened on the Glen Innes Company's property, which adjoins that of the Kingsgate Company. The Company is now sinking upon a vein which is said to have been 1 foot wide at the surface, but when I saw it at a depth of 40 feet, the lowest level then reached, it was 4 feet wide. This vein is in granite and close to the boundary of the slate formation. The vein-stuff is thickly studded with large brilliant steel-grey plates of molybdenite, some of them being more than 3 inches in diameter. Nodules of native bismuth, larger than walnuts, with carbonate, sulphide, and oxide of bismuth, occur through the vein, and in greater quantity in places where the molybdenite becomes abundant.

Another vein situated about 100 yards from this contains, besides bismuth ore and molybdenite, some arsenical pyrites, which latter yielded on assay 9·2 per cent. of metallic bismuth, fine silver at the rate of 92 oz. 14 dwt. per ton, and no gold.

About 3 miles east from the Yarrow Creek Head Station, and about the same distance in a south-easterly direction from Kingsgate, is the Comstock Bismuth Company's mine. No work was being done here at the time of our visit; but we saw three pipe-veins of hard white crystalline quartz which had been opened for only a few feet from the surface. The shafts were partly filled with water, so that the exact size of the veins could not be measured, but the largest of them appeared to be about 6 feet by 15 feet near the surface. A sample of bismuth ore collected from the heaps gave on assay:—

Metallic bismuth, 35·6 per cent.
Fine gold, at the rate of 2 oz. 9 dwt. per ton.
Fine silver, at the rate of 9 oz. 16 dwt. per ton.

Thus, again, we see that the bismuth ore contains gold. These veins are also in granite, and distant about 200 yards from the slate formation.

It is a somewhat remarkable feature that all the bismuth veins (eighteen) as yet found occur in the granite within a short distance from the slate; and it is probable that on further examination of the country along the line of junction of the two formations other veins will be discovered. The bismuth lode in the Silent Grove Mine occurs under the same conditions, namely, in granite close to its junction with altered slates, and it is of similar character to those above described."*

The rocks in the vicinity of the mines consist of granites, apparently late or post-Permo-Carboniferous in age, and of claystone and allied rock types of unknown age, but possibly Permo-Carboniferous, The sediments have been intruded by the granite, and, as may be seen by reference to the

* Annual Report, 1883, p. 154.

PLAN SHOWING
THE KINGSGATE

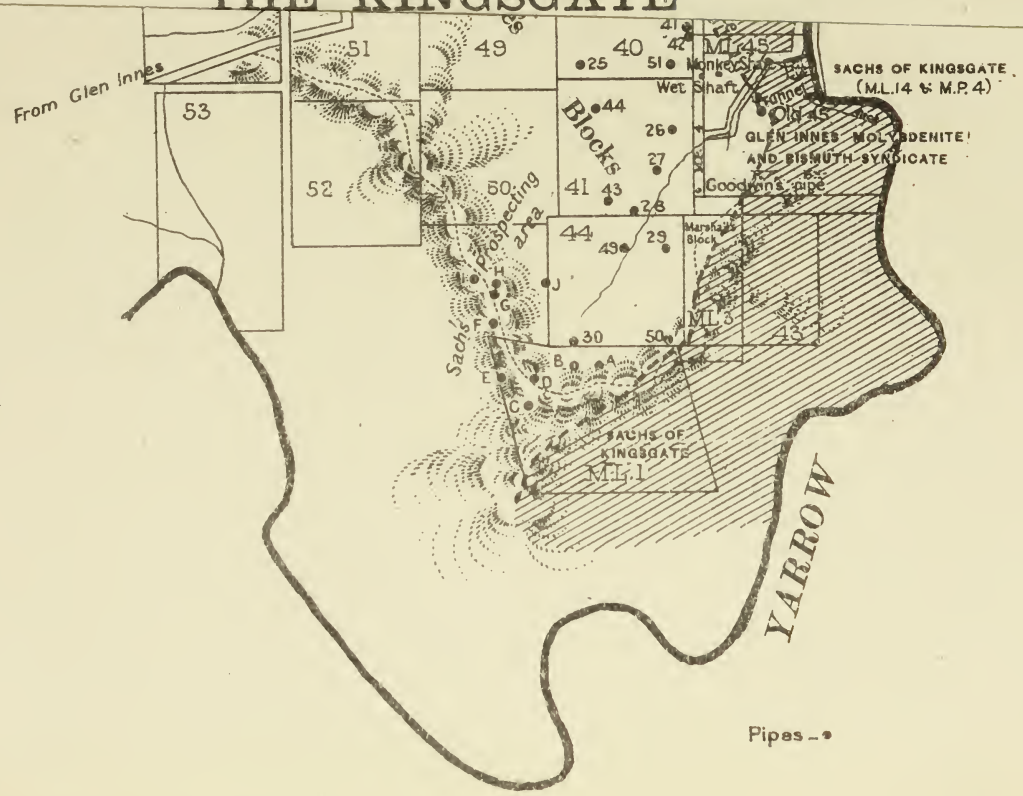
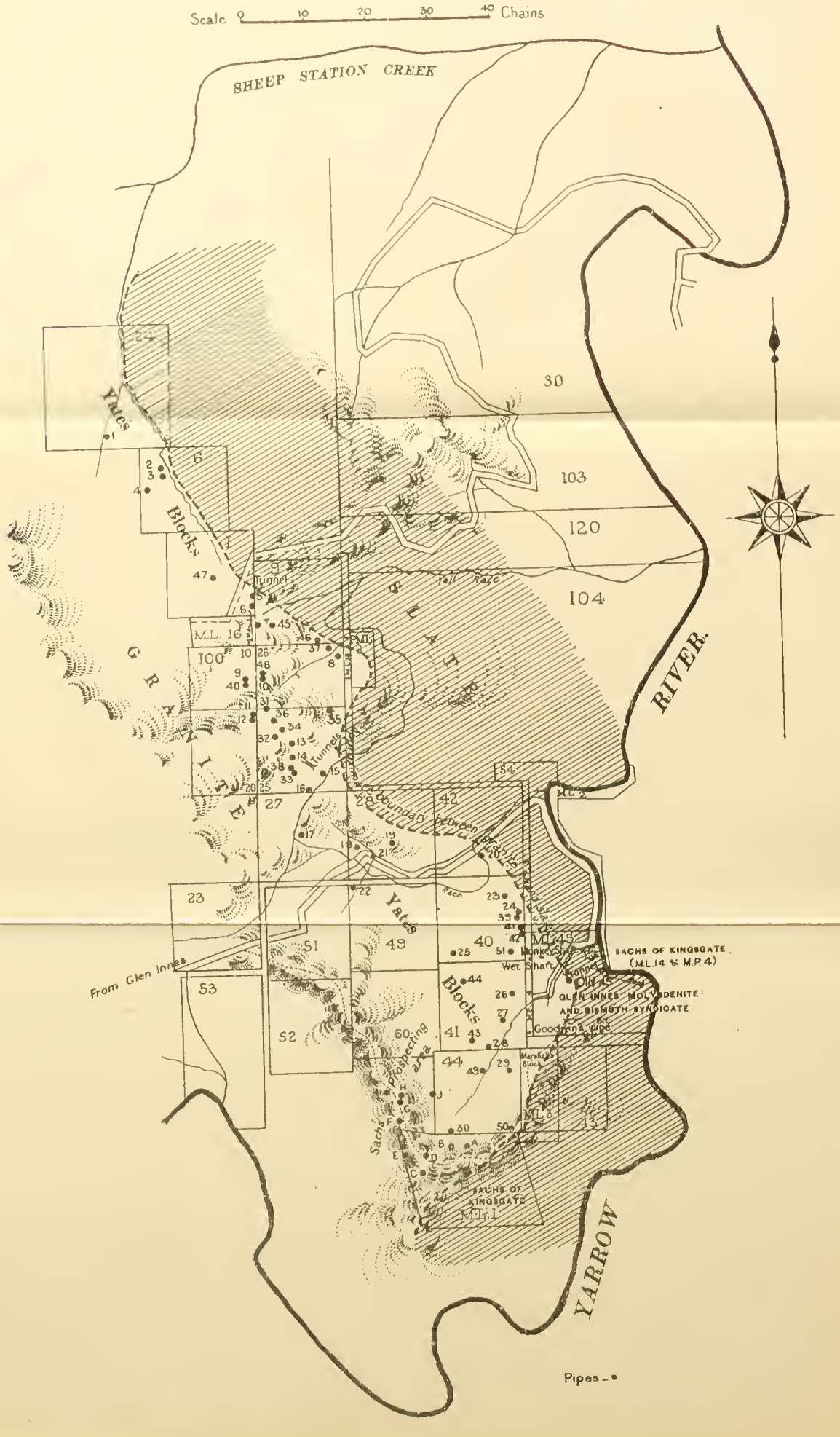


PHOTO-LITHOGRAPHED BY W.A. GULLICK, GOVT. PRINTER, N.S.W.

PLAN SHOWING

THE KINGSGATE BISMUTH—MOLYBDENITE—QUARTZ PIPES

PARISH OF KINGSGATE COUNTY OF GOUGH



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accompanying map, the molybdenite deposits are all situated within the granite and in proximity to its intrusive contact with the claystone. The pipes dip toward the contact in the main, but they exhibit marked local deviations from this general trend. The inclination of the deposits is not uniform, but, in places, is suggestive rather of a series of irregular steps and treads. As examples of such a feature, the cases of the No. 40 North, the Arsenic Blow, the Nos. 1 and 9 and the Old 45, especially the latter, may be cited [*see* Map opposite page 94]. The average angle of dip of Yates' pipes is said to be about 30 degrees. Near the surface certain of the pipes branch in a pronounced manner, a condition noted also in the Whipstick Mountain pipes. The depths at which these pipes branch varies, but an examination of the pipes themselves suggests that they tend to show branches in proportion to their nearness to the surface.

The size in cross-section is very variable, being from 3 to 60 feet in greatest diameter [*see* Map]. The size in cross-section may vary considerably, even in the same pipe; thus in the No. 45 the large chamber which produced the rich molybdenite was about 20 feet in diameter, whereas, immediately below this chamber the pipe had contracted to an extent such that it did not exceed 18 inches in diameter. The No. 40 Pipe also is of very variable size in cross-section, as shown in the workings.

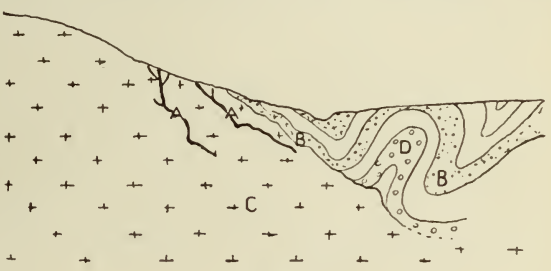

Fig. 11.

Ideal section across contact of coarse granite and claystones at Kingsgate.

A—Pipes of quartz containing molybdenite and bismuth.
B—Granite and claystone contact.
C—Coarse siliceous granite.
D—Claystone of age unknown (Permo-Carboniferous or older).

The depths to which pipes may persist from the surface is also instructive. Thus the 25 North has been worked to a depth exceeding 500 feet as measured along the underlie and it is still " strong " in the face.

Pipes, again, in Kingsgate may branch upwards and outwards, or the branches may dip downwards. In the first case the bifurcations are known as branches, in the latter case, " droppers." Pipes may split and join again. This feature was observed also at Goodwin's Pipe at Wunglebung, on the Rocky River.

The granite containing the molybdenite at Kingsgate is coarse, granular, without large crystals of felspar. Moreover, it is not very siliceous, probably containing not more than 72 per cent. silica on the average. It presents marked differences, however, from the typical dark granites of the Glen Innes district. In areas occupied by these dark or hornblende granites of the large Glen Innes district the land is park-like and the characteristic plants are the red or black peppermint (*Eucalyptus nova anglica*), the black sally (*E. stellulata*), the white sally (*E. coriacea*), all growing in clumps associated with large and small open spaces, generally well grassed. Here and there a red stringybark (*Eucalyptus eugenioides*) and a honeysuckle

(*Banksia integrifolia*) may be found. The molybdenite granite of Kingsgate, however, supports abundant growths of white peppermint (*Eucalyptus Bridgesiana*), red stringybark (*E. eugenioides*), brown gum (*E. Deaneii*), narrow-leaved stringybark or peppermint (*E. amygdalina*), messmate (*E. obliqua*), white gum (*E. viminalis*), apple tree (*Angophora subvelutina*), honeysuckle (*Banksia integrifolia*), and dense thickets of black oak (*Casuarina suberosa*). Dense undergrowths are uncommon, such being characteristic, however, of the tin and wolfram granite of Oban, Mount Mitchell, and Backwater, some miles to the south and east.

The molybdenite granite is very much like the granite of Bow Creek and Splitter's Swamp at Bolivia (pp. 63, 75), both in general appearance and in the class of vegetation.

The arrangement of the molybdenite and the bismuth in the pipes is peculiar and interesting. As a rule, according to the statement of Mr. W. H. Yates, the greater proportion of the minerals under consideration occurs in the more marginal portion of the pipes, almost in the form of a wide collar, as seen in cross-section, leaving the central portions of the pipes as masses of quartz containing but little proportion of the valuable minerals. Nevertheless, the richer portions of the pipes, especially as regards the bismuth contents, occur in what is known as the "gutter," or "footwall," part of the pipe, consisting of brown or grey cavernous and finely-textured quartz, while the upper, or hanging-wall portion, is neglected by the miners in certain pipes of large diameter. Thus the Old 40 had a diameter in cross-section exceeding 65 feet (Plate XI); nevertheless, only the lower, or footwall, portion has been worked below the open cut. The map illustrates the comparative size of the pipe, as worked or stoped, in the open cut, and at a great distance below the open cut.

History.—For the accompanying notes on the history of mining at Kingsgate I am indebted to the courtesy of Mr. W. H. Yates, who supplied me with letters, original documents, and with personal communications concerning the early days at this important and interesting field.

It would appear that land was secured in 1872 for purposes of tin-mining by an Adelaide company, and the pipe, known as the Wolfram Pipe, or Old No. 26, was the first to be prospected. No. 7 Pipe, or the Water Shaft, at this time was found to contain tin oxide in the outcrop; the yield, however, of tin was quite insignificant, and mining operations there were abandoned.

These deposits, namely, the tin and wolfram pipes, occur towards the northern end of Yates' mineral conditional purchases, and the outcrops both of these, and of the associated pipes to the south, appeared strange to the old tin-miners, consisting, as they did, of quartz white in colour, small and large in size, more or less circular in shape, and the peculiar nature of the enclosing granite. At that time neither bismuth nor molybdenite had been detected in the outcrops of quartz, nor had anyone noted the peculiar distribution of the pipes within the granite, namely, close to its intrusive contact with the claystone.

The field had thus been "weighed and found wanting" by the tin-miners, but about five years later (1877) a stockrider on Yarrow Creek Station, named J. Feeney, picked up a large piece of a metallic mineral on the surface. This was sent to Sydney for determination and was ascertained to be native bismuth.

Hereupon the Kingsgate district entered upon another period of activity. Feeney had proved the existence of native bismuth in the vicinity of the old Tin Pipe. About the same time Hughie Quinn, a prospector, while walking

across Leatherjacket Hill, noticed a fine patch of yellow incrustations on the quartz forming the outcrop of the pipe now known as No. 5. Impressed by the appearance of these he took some of the material to Mr. Yates, who, at that time, was tin-mining on the Severn River, near Bald Nob. Quinn appeared to believe it was sulphur. The mineral was determined to be bismuth ochre by Mr. Yates, and was shown to Mr. Ferguson, a member of Parliament at that time. Mr. Ferguson advised mining for bismuth, and it was decided thereupon to secure the land upon which the deposits were known to outcrop. Originally 80 acres of land had been taken up as tin leases in four blocks each of 20 acres, namely, Nos. 10, 20, 25, and 26, and in 1879 Quinn and Ferguson took up 60 acres of this land in one block and which is known now as Block No. 100. As a result of this action on the part of Quinn and Ferguson, Feeney, together with John Rush and another called Say, secured a block lower down the gully, known as Number Six, and this block thus became known as No. 6. A mild excitement was caused thereby in local mining circles, and Quinn gave certain information to Mr. Yates, which led to the latter proceeding to a locality known to the Kingsgate residents as Cattle Camp, at which a large outcrop of quartz was known to occur. Mr. Yates took a sample of the rubble on the outcrop to the Yarrow Creek alongside, and from a dishful of the material selected he washed out two or three pounds weight of native bismuth, as also a single nugget of this metal weighing about three pounds. Mr. Yates thereupon secured the block, which is known as No. 40. This was in 1880.

About this time Mr. Lewis, a storekeeper of Glen Innes, bought No. 6 from Mr. Feeney, and the idea of amalgamation suggested itself to the various holders of the portions, which were more or less isolated the one from the other. The Kingsgate Bismuth Company was thus formed, and it was agreed by the holders that the country lying between the various portions already in their possession should be secured for purposes of consolidation, and that any land in the neighbourhood which contained quartz outcrops should be secured also.

The area known now as No. 45 Block was not secured by the Kingsgate Bismuth Company, inasmuch as the fine quartz outcrops on that land were not observed by any member of the Company. Moreover, the failure to find these outcrops, or to secure this land (*see* Map) was due, in great measure, to non-recognition of the fact that the bismuth deposits occur near the great granite-claystone contact of the district. The action of the subject holders in consolidating their isolated properties and securing fresh ground led to prospecting operations on the part of other parties, and as a result of such activity on the part of the " Glen Innes Company " the famous No. 45 Pipe was found, and an area of 25 acres was secured by this later Company for the protection of the area. The ore mined in this block contained bismuth, and the " Glen Innes Company " sent the concentrated material up a spur on their land [Map] between the years 1880 and 1890. During this period also, they simplified their original mining operations by driving a tunnel into the hillside and thus avoiding a certain amount of haulage on an underlie. The pipe contained much molybdenite, but at that time it was considered only as an impurity in the bismuth ore. Inasmuch as the bismuth content at that period was insufficient to return working expenses, the mine was closed in 1890 and the land remained unoccupied for about six years. Several miners appear to have worked it subsequently, but the deposit lay idle from the years 1898 to 1901, at which latter date the late

Mr. Valentine Sachs secured a lease of the No. 45 Block, and he commenced to send ore to Sydney in 1902 from the pipe, the ore being carted along the private road through the Kingsgate Freehold. A large and rich patch of molybdenite and bismuth ore was found by Mr. Sachs at a place where the pipe had been enlarged considerably. One very large piece of pure molybdenite was found in the great chamber excavated in the enlargement. The piece exceeded a ton in weight and had to be torn in pieces before it could be brought to the surface [*Frontispiece*]. A chamber about 60 feet in length, with a width and height varying from 12 to 25 feet, was excavated in the enlargement, and many tons of molybdenite were won therefrom.

The continuation of the pipe was lost, however, by Mr. Sachs, and after an eventful history the mine was acquired in 1912 by the Glen Innes Molybdenite and Bismuth Company; and in the same year the company known as the "Sachs of Kingsgate Molybdenite and Bismuth Syndicate" took up a lease for mining over a road lying between Mr. Yates' Freehold and the Glen Innes Molybdenite and Bismuth Company's lease (*see* Kingsgate map).

The newcomers experienced great difficulty in finding the continuation of the 45-pipe below the great chamber excavated by Mr. Sachs. It was found, however, to have suffered a local constriction, the quartz immediately below the chamber not exceeding 18 inches in diameter and having a vertical direction.

It may be interesting, at this stage, to return to the consideration of the freehold land. After the consolidation of the old mining areas and the purchase of the land in the vicinity which was considered likely to contain bismuth deposits of importance, the Kingsgate Bismuth Company worked the mines, rejecting the molybdenite and saving the bismuth. In 1883 the properties were purchased by Messrs. David Marks and E. Vickery, who worked the deposits steadily, with Mr. W. H. Yates as manager, until 1889 or thereabouts. The number of men employed was about forty. Two of the earliest works to be carried to completion by Messrs. Marks and Vickery were the construction of a private road and a long water-race. The private road was said to have involved an outlay of £350 on construction and upkeep, and the water-race was cut for a distance of 3 miles from the Yarrow River, at a cost of £1,000. No molybdenite was saved, excepting a few tons mined and despatched in 1885 and 1887. This venture, however, proved to be a dismal failure from a financial point of view.

The mines remained idle from 1889 till 1893, because of the cost entailed in winning the bismuth with the primitive appliances in use at that time. The method in vogue at that time appears to have been much as that described in the accompanying note :—

"The ore was first hand-picked at the mine, and was then carted about half a mile to the concentrating works. Here it was put through a Blake crusher, driven by a waterwheel. It was generally crushed twice, or until it all passed through the grating of an inclined trommel having a mesh of four holes to the inch. The crushed material was then treated in a sluice box having a fall of 9 inches in a length of 12 feet. While being sluiced it was worked gently with a shovel, and also with a birch broom, and by these means concentrates of 20 per cent. grade were obtained. These concentrates were again treated in a smaller sluice-box with a slighter fall, and in this way they were cleaned to a 50 per cent. tenor. The finely-crushed molybdenite was all got rid of by gently stirring the contents of the sluice-box with the

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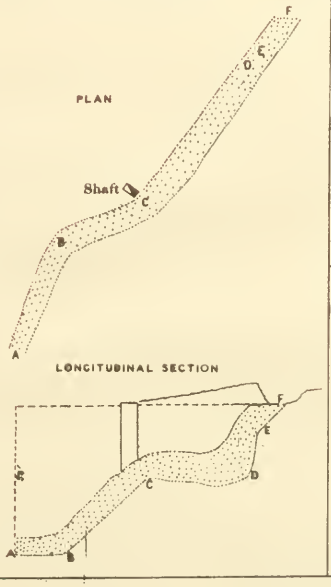
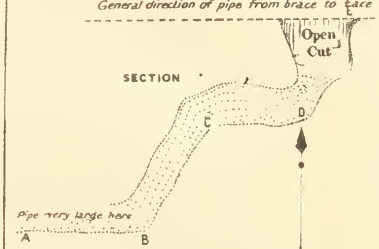
PLANS AND PROJECTED SECTIONS OF MOLYBDENITE AND BISMUTH PIPES AT KINGSGATE

Scale 0 20 40 Feet

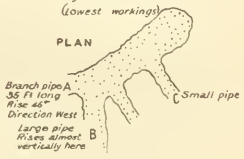
PIPE NO. 21
Arsenic Blow known as No. 41



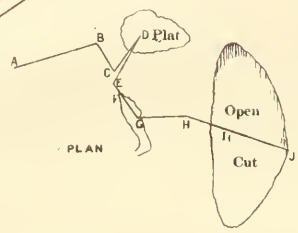
PIPE NO. 23
known as No.40 North

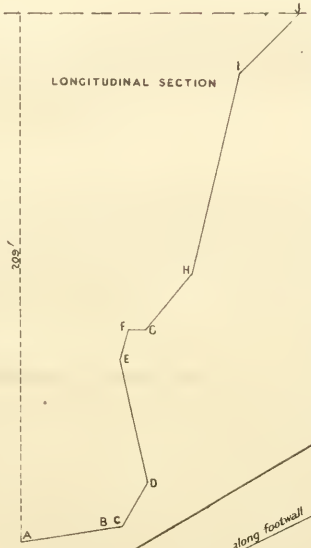


NO. 5 OR 1 & 9 TUNNEL
(Lowest workings)

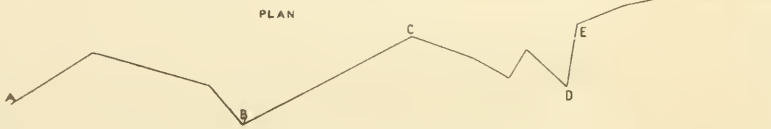


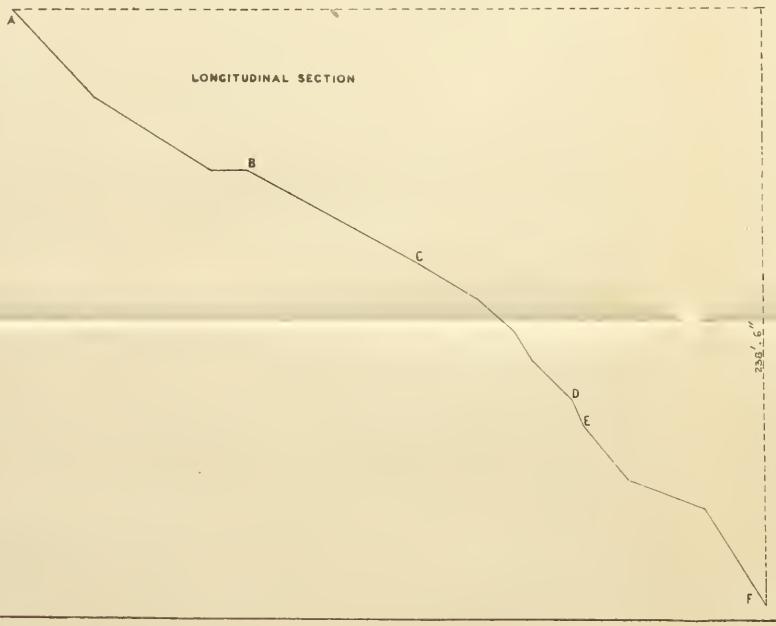
PIPE NO. 24
known as No. 40

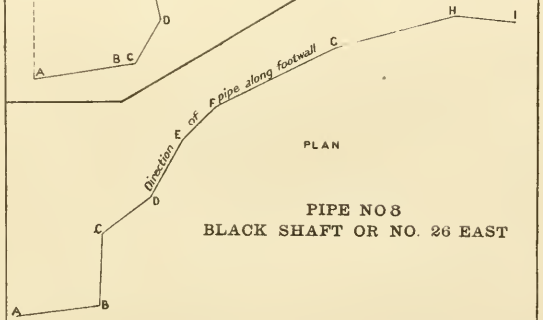




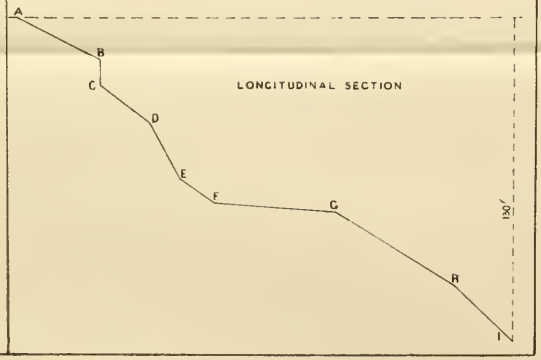
PIPE NO. 13
known as 25 North







PIPE NO 8
BLACK SHAFT OR NO. 26 EAST



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shovel and broom; the concentrates were afterwards dried and sifted, and the coarse fragments of molybdenite picked out by hand. The ore thus cleaned was exported."*

During the period 1883–1889 Messrs. Marks and Vickery produced 216 tons 7 cwt. of concentrate, containing 45 per cent. bismuth, at a cost, including improvements, of £37,118 to the Company.

The mines remained idle from 1890 until 1893, partly because of the cost entailed in the employment of the primitive sluice-box in concentration and partly because of the low price ruling at that time for bismuth. During 1893 Mr. Yates worked the mines on a basis of royalty, the mines being sublet on tribute and subject also to certain other conditions.

Mr. Yates purchased the property in 1905 from Messrs. Marks and Vickery. Thenceforward until 1912 the various deposits were worked in part on wages and in part on contract. In 1912, however, it was decided to erect mills for the concentration of the molybdenite and bismuth, and the mill, known as No. 40, was completed about the close of that year, while the Top, or Upper, mill was completed at the close of 1913. The mines were then worked on the system of day wages, the average number of men employed being about thirty-five.

Production.

(*a*) Yates' Property.

Period 1880 to 1882.—Concentrate produced to the amount of 21½ tons, averaging 60 per cent. bismuth. No molybdenite saved.

Period 1883 to 1889.—About 216 tons 7 cwt. of concentrate produced, averaging 45 per cent. bismuth.

4 tons of molybdenite saved, but the price realised on the sale of same was less than the costs of mining, treatment, and realisation.

Period 1894–1911.—About 68 tons 8 cwt. of concentrate produced, averaging 45 per cent. bismuth.

Also about 104 tons 14 cwt. concentrate, averaging 93 per cent. molybdenite produced and sold.

1912.—5 cwt. bismuth concentrate, valued at £50; 10 cwt. concentrate containing 90 per cent. molybdenite, valued at £100.

This mineral was won from Yates' road lease.

1913.—6 cwt. concentrate, containing 27 per cent. bismuth, and valued at £45.

16½ cwt. concentrate, containing 90 per cent. molybdenite, valued at £223.

1914.—9½ tons concentrate, containing 35 per cent. bismuth, valued at £2,850.

8¾ tons concentrate, containing 94 per cent. molybdenite, valued at £4,700.

1915.—12 tons of molybdenite concentrate (93 per cent. MoS_2), valued at £5,340.

17¾ tons bismuth concentrate, valued at £5,680.

1916.—Till June, 9¼ tons molybdenite; 8¾ tons bismuth (50 per cent.).

(*b*) The Old 45, or Sachs' Pipe.

The returns from the mine of this name are not at all complete, as no statement was supplied during certain years in response to official inquiry as to the yield of bismuth and molybdenite.

* Pittman, E. F. Mineral Resources, 1901, p. 260.

The accompanying table has been compiled from the various official sources.

Year.	Molybdenite.	Value.	Bismuth.	Value.
	Tons.	£	Tons.	£
1902	11·1 concentrate ...	2,000	No return furnished.	
1903	No return furnished ...	.....	,, ,,	
1904	400 ore	6,124	,, ,,	
1905	No return furnished ...	.....	,, ,,	
1906	15 concentrate	2,000	20 concentrate	5,200
1907	15 ,, ...	2,000	No return furnished.	
1908	10 ,, ...	1,200	4 concentrate	1,000
1909	5 ,, ...	500	1½ ,, ...	500
1910	No return	.....	No return.	
1911	,, ...	.....	,,	
1912	2·05 concentrate ...	Unknown.	1·15 concentrate ...	Unknown.
1913	No return	.....	No return.	
1914	1·60 concentrate ...	655		500
1915	.....	.....	.....	.....
1916	.....	.....	.....	.....

NOTE.—Prior to 1902 bismuth returns unknown; none for molybdenite.

(*c*) Sachs of Kingsgate.

The pipes under this control were worked by individual miners prior to 1914, and their production before that date is not known.

1914.—17 cwt. molybdenite concentrate, valued at £340.

1915.—131 tons ore mined; 100 tons treated yielded 1 ton 11 cwt. concentrate exceeding 90 per cent. molybdenite; 31 tons 10 per cent. bismuth ore raised, not despatched.

1916.—Unknown.

Descriptions of individual pipes at Kingsgate.

(*a*) Yates' Pipes.

The accompanying table has been supplied by Mr. W. H. Yates, and is a schedule of his pipes, giving the distinguishing numbers of individual pipes as indicated on the sketch map of Kingsgate herewith, the numbers of the individual portions containing the pipes, the approximate lengths of the pipes, in 1915, as measured along their underlie, the average slopes of individual pipes, and the average or maximum size of the individual deposits in sections approximately horizontal or at right angles to the general underlie.

A few only of the more important pipes, from the commercial and scientific point of view, have been selected for individual description.

On an alphabetical arrangement of the Kingsgate pipes, the description of Sachs', O'Donnell's, and other claims should have been treated first. The importance of the Yates' property, however, has justified their description prior to the others.

The returns of individual pipes are not supplied. A description of the two treatment plants is to be found on pages 9, 10.

In addition to the large area of land held under Mineral Conditional Purchase, Mr. Yates also holds Portion M.P. 5 of 2½ acres, approximately, over portion of a road lying between Portions 40, 42, and 54.

Schedule of Pipes, Kingsgate.

No. of Deposit.	No. of Portion.	Position of Deposit.	Known as—	Length worked on Pipe exclusive of Branches.	Average Slope.	Size of Pipe in bottom at end of year 1911.
1	24	10 ch. W. from S.E. corner of Por. 24, thence 2 ch. N. ...	Quinn's Find... ...	*	.....	
2	6	3½ ch. E. from N.W. corner of Por. 6, thence 3½ ch. S. ...	No. 6	50 ft. (approx.)...	1 in 2 ...	3 pipes 10 x 10 each (approx.).
3	6	3½ ch. E. from N.W. corner of Por. 6, thence 4½ ch. S. ...	.....	.....	.....	
4	6	7 ch. S. from N.W. corner of Por. 6, thence 1 ch. E. ...	.....	40 ft (approx)...	Vertical	20 x 20.
5	1 and 9	5½ ch. S. from N.W. corner of Por. 9 on line between 1 and 9 (One and Nine tunnel).	One and Nine ...	282 ft.	1 in 2 ...	25 x 15.
6	1	Near the S.E. corner of Por. 1 in block 1	.....	.....	.....	
7	1 and 9	1 ch. S. from S.E. corner of 1, on W. line of 9	Water Shaft (or Tin Show).	40 ft. (approx.)...	Vertical	6 x 6 (approx.).
8	100	Near N.E. corner of 100, in 26	Black Shaft (or 26 East).	311 ft.	1 in 2 ...	
9	100	4½ ch. N. from S.W. corner of 26, thence 2 ch. W. ...	Bill Miller's Hole	33	Vertical	20 x 20 (approx.).
10	100	4½ ch. N. from S.W. corner of 26, thence ½ ch. E. ...	Old 26 (or Little Tunnel).	100 ft. (approx.)	1 in 2 ...	12 x 12 (approx.).
11	100	1 ch. S. from S.W. corner of 26, thence 1 ch. W. ...	Mick's Shaft	100 ft. (approx.)	1 in 1 ...	20 x 20 (approx.).
12	100	2 ch. S. from S.W. corner of 26, thence 1 ch. W. ...	.....	*	.....	
13	100	6 ch. S. from S.W. corner of 26, thence 5 ch. E. ...	25 North	500 ft. (approx.)	1 in 2 ...	15 x 20.
14	100	8 ch. S. from S.W. corner of 26, thence 5 ch. E ...	Old 25	250 ft.	1 in 1 ...	40 x 40 (approx.).
15	100	4 ch. W. from S.E. corner of 25, thence 3 ch. N. ...	Weidmeyer's Cutting	100 ft.	Vertical	16 x 8.
16	100 and 27.	6 ch. W. from S.E. corner of 25, on line of 25 and 27 ...	Martin's Hole ...	50 ft.	Vertical	12 x 12.
17	27	Near centre of block 27, in the gully	.....	.....	.....	
18	27 and 28	5 ch. N. from S.W. corner of 28, on line of 27 and 28 ...	Schoolhouse Blow.....	.....	.....	
19	28	7 ch. W. from S.E. corner of 28, thence 5½ ch. N. ...	Magazine (or Windlass Shaft).			
20	42	6½ ch. E. from S.W. corner of 42, thence 3 ch. N. ...	.....	.....	.....	
21	28	7 ch. W. from S.E. corner of 28, thence 2 ch. N. ...	28 South (below road)	*	.....	
22	49	1½ ch. E. from N.W. corner of 49, on N. line of 49 ...	.....	.....	.....	
23	40	3 ch. W. from N.E. corner of 40, thence 3 ch. S. ...	Forty North	200 ft. (approx.)	1 in 1 ...	4 pipes, 10 x 12 largest.

* Prospected on surface only † Worked along footwall only. ‡ Three additional pipes have been found in the southern portion of Block 24 during 1916.

SCHEDULE of Pipes, Kingsgate—*continued.*

No. of Deposit.	No. of Portion.	Position of Deposit.	Known as—	Length worked on Pipe exclusive of Branches.	Average Slope.	Size of Pipe in bottom at end of year 1911.
24	40	5½ ch. S. from N.E. corner of 40, thence ½ ch. W. ...	Forty	300 ft. (approx.)	Vertical	† 16 x 13.
25	40	2½ ch. E. from S.W. corner of 40, thence 1½ N.... ...	Forty South	60 ft. (approx.)...	Vertical	† 20 x 20.
26	41	5 ch. S. of N.E. corner of Por. 41, thence 3 ch. W. ...	Jim Marshall's Hole...	*	.....	
27	41	5 ch. N. of S.E. corner of Por. 41, thence 4 ch. W. ...	.....	.....	.....	
28	41	6½ ch. W. of S.E. corner of Por. 41, thence 10 ft. N. ...	Arsenic Blow ...	205 ft. (approx.)	1 in 2 ...	† 8 x 8.
29	44	3 ch. S. of N.E. corner of Por. 44, thence 2 ch. W. ...	Hard Blow	50 ft.	Vertical	.....
30	44	2½ ch. E. of S.W. corner of Por. 44, thence ½ ch. N. ...	Sachs' Folly	*	.....	
31	100	1 ch E. of N.W. corner of Por 25, on line of 25 and 26	.....	*	.....	
32	100	5 ch. E. of N.W. corner of Por. 25, thence 2½ ch. E. ...	25 West.	*	.....	
33	100	2½ ch. S. from deposit No. 14	25 South	35 ft.	Vertical	8 x 10
34	100	2 ch. 70 lks. N.N.W. from deposit No. 13	Mt. Morgan	225 ft.	1 in 2 ...	15 x 10.
35	100	2 ch. 80 lks. from N.E. corner Por. 25, just in 25 ...	Granite Shaft ...	150 ft. (approx.)	1 in 1 ...	13 x 13.
36	100	3 ch. S.E. from N.W. corner Por. 25, and 2 ch. N.W. from deposit 34.	25 N.W., No. 2 ...	50 ft.	1 in 1 ...	3 x 2.
37	9 and 100	2½ ch. W. from S.E. corner Por. 9 on line between 9 and 26.	Tom Key's Hole (or Chimney Shaft).	150 ft.	1 in 1 ...	12 x 12 (approx.).
38	100	40 ft. N.W. from deposit No. 33	25 South, No. 2 ...	32 ft.	Vertical	14 x 7.
39	40	Near deposit No. 24	.....	.....	.....	
40	100	1 ch. S. from deposit No. 9	Jubilee	*	.....	
41	40	2 ch. S. from deposit No. 24	Road Block	60 ft.	1 in 1 ...	8 x 8.
42	40	70 yds. S. of 40 hole, on surveyed line	.....	.....	.....	
43	41	3 ch. 10 deg. N.W. from above Arsenic Blow	Christie's Blow ...	.....	.....	
44	41	4 or 5 ch. from N.W. corner of 41, and uphill from Christie's Blow.	.....	*	.....	
45	9	2½ ch. E. of Tin Shaft, *i.e.*, No. 7	Jack's at Home ...	*	.....	
46	9	1½ ch. W. of the Chimney Shaft, *i.e.*, No. 37	.....	*	.....	
47	1	In swamp below the cottage	Swamp Blow ...	*	.....	
48	100	About 1 ch. N. from Little Tunnel, deposit No. 10 ...	.....	.....	.....	
49	44	.....	.....	.....	.....	
50	44	Near S.E. corner	Nield's Blow... ...	.....	.....	
‡51	40	.....	Reef Blow	.....	.....	

* Prospected on surface only. † Worked along footwall only. ‡ Three additional pipes have been found in the southern portion of Block 24 during 1916.

Order of description observed.

Kingsgate Proper, Parish Kingsgate.

A. Yates' Pipes.
   1. Arsenic Blow, or Hagen's Tribute.
   2. Black Shaft, or No. 8.
   3. Forty.
   4. Forty North.
   5. Granite Shaft.
   6. Mount Morgan.
   7. One and Nine, or No. 5.
   8. Reef Blow.
   9. Tin Shaft.
   10. Twenty-five North.
   11. Wolfram Blow.

B. Block, or Portion, 45.
   1. Monkey Shaft.
   2. Old 45, or Sachs' Pipe.

C. Sachs of Kingsgate Syndicate.
   1. Goodwin's Pipe.
   2. Prospecting Area.
   3. Wet Shaft or Water Cut.

D. Speckhardt (Pauline) and Others.
   M.L.1.

E. Lancaster's, O'Donnell's, and Others, Claims.

F. Yarrow Creek, Parish Yarrow.
   1. Maurer's Claim and other small claims.

A. Yates' Pipes.

1. Arsenic Blow, or Hagen's Tribute. No. 28 on accompanying list. Situated on Portion 41.

The pipe is of quartz, and the greatest length measured along the underlie is about 205 feet. It was worked in the early days by means of an open cut, and in more recent time as an underlie shaft. Latterly a vertical shaft, from 35 to 40 feet deep, has been sunk to permit the working of the deposit in a more economical manner.

In vertical section the pipe forms a set of irregular "steps" and "treads," as may be seen by reference to the map. The deposit is large, averaging 8 to 10 feet in diameter. The greatest measurement in cross-section is about 15 feet.

A considerable amount of bismuth and molybdenite has been won from the mine, especially from the position known as the "footwall." At the lowest point, or the "gutter" of this footwall, the felspars of the granite have been altered, in great measure, to nests and flakes of soft mica. Immediately above this lies a quartz mass, brown, compact, or cavernous, of fine texture, and containing bismuth with a little molybdenite. Black quartz, crystalline or massive, cavernous or compact, fine or coarse in texture, with molybdenite, overlies this in turn. This association passes upwards by stages into white or grey quartz, either massive or in large crystals, either well-jointed and brittle or compact, or containing caverns as much as 10 feet in length.

2. Black Shaft, or No. 26 East. No. 8 on the attached list. Situated on Portion 100.

This deposit is a very large body of quartz, and it is said to have a diameter of 30 or 40 feet. It has been proved to a depth exceeding 310 feet on the underlie. (*See* Map.) It was followed in an easterly or north-easterly direction for a distance of 130 feet approximately, thence it was found to have a north-westerly dip, while lower down it was again traced in an easterly direction.

The directions of the mine workings, in plan and vertical projection, are shown on the map.

Plate XI illustrates the surface workings.

The subject deposit is one of the famous pipes, of Kingsgate. Unfortunately the workings were inaccessible during my visit, otherwise a fuller description of this important pipe would have been supplied.

3. Forty. No. 24 on the attached list. Situated on Portion 40.

This deposit had an enormous outcrop of white quartz, which yielded rich returns of bismuth from the loose rubble at the surface.

The deposit was worked by means of an open cut to a depth exceeding 20 feet. Plate XI illustrates the great size of the pipe. The open cut, which is here depicted, was excavated simply by the removal of the outcrop and upper portion of the deposit. The excavation has been filled in great measure. The longest cross measurement was about 70 feet. (Pl. XII and Map.)

In this open cut the whole of the upper portion of the deposit was mined and an enormous quantity of bismuth is reported to have been obtained therefrom. This work was done in the earlier days of mining in this locality.

At a later date a tribute was taken by Mr. Henry Marshall and others, and the pipe was worked to a depth of 90 feet from the surface. It had been noted by the miners who made the open cut that the best deposits of bismuth occurred along the "footwall," and accordingly Mr. Marshall worked the "footwall" side of the deposit below the bottom of the open cut, leaving the great mass of the deposit, or that known locally as the "Hanging Wall," untouched.

Since the year 1911 Mr. Yates has worked this fine pipe, and in 1915 the total length of the workings along the footwall was 300 feet.

The accompanying plan and vertical projection illustrate the occurrence. (Map 4.) The "Hanging Wall" has not been exposed at a depth exceeding 50 feet from the surface, but it is to be hoped that this portion may be prospected at some point or points.

In September, 1915, the "footwall" deposit was relatively small, and did not contain much ore of first-class quality. This feature, however, is one which is expected and which does not cause anxiety necessarily in pipe-mining in New England, inasmuch as a pipe is expected to have an alternation of rich and poor patches, as well as constrictions and expansions in cross measurements.

Fig. 12 illustrates this local pinch in the "footwall" portion of the pipe, while Fig. 13 illustrates the general sequence of minerals from the "footwall" upwards in the pipe.

This deposit also is one of the important ones of the locality.

4. Forty North. No. 23 on accompanying list. Situated on Portion 40.

This deposit is a quartz pipe, which has been mined for a distance exceeding 200 feet as measured along the underlie. It is a very large and

(*a*) Open cut of No. 1 and 9 (5) Pipe. Yates' Property, Kingsgate.

(*b*) Lower Plant. Yates' Property, Kingsgate.

important mine, but one which, at the surface, was so poor that it was abandoned by the prospectors. A sluice, however, which had been cut in the rotten granite just below the deposit by a discharge from a race exposed the quartz for a depth of 20 feet below the surface, and at this depth it was seen to contain a large quantity of bismuth ore. The deposit was worked then at a very steep angle to a depth of 43 feet, thence at a very low angle it was followed for 40 feet. Below this point the deposit pitched at an angle of 60 degrees approximately for a distance of 50 feet, thence for a distance of 50 feet the deposit has been traced in a horizontal direction. At this, the lowest point worked, the deposit was about 30 feet wide in September, 1915. In the large excavation formed by the removal of this horizontal portion of the deposit, the granite country has been exposed under foot, and pitching very gently on both sides from a central ridge of blunt nature, which runs along the main axis of the pipe in this portion of the mine.

Fig. 12.

Sketch of face on "footwall" during September, 1915, at a depth of 300 feet in No. 40 Pipe, Kingsgate.

A—Coarse white quartz in large crystals or in large brittle masses.
B—Brown or smoky quartz either tight, cavernous, or granular, with crystals, with molybdenite.
C—Brown compact or cavernous quartz with much native bismuth.
D—Coarse siliceous granite.
E—Granite with felspars converted into hydrous mica.

In the bottom workings it was noted that quartz, brown or dark-grey in colour, honeycombed and fine in texture, and containing rich bismuth and molybdenite, rests upon the granite and continues to a height of 6 feet above the floor of the excavation. The basal portion is by far the richest. This dark quartz passes upward into massive, jointed and crystalline white quartz. Fig. 13 illustrates a sketch section across the lower workings, while the plan and vertical projection of the deposit are shown on the accompanying map of various mine workings.

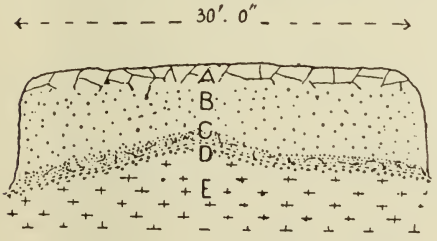


Fig. 13.

Sketch section of face in No. 40 North Pipe, September, 1915.

A—Massive jointed and crystalline white quartz.
B—Fine grained, cavernous, black and dark grey quartz, with bismuth and molybdenite.
C—Rich bismuth with molybdenite in dark granular quartz.
D—Granite with felspar altered to soft mica.
E—Coarse siliceous granite.

5. Granite Shaft or Pipe. No. 35 on accompanying list. Situated on Portion 100.

The deposit is a granite pipe containing quartz in masses.

The pipe is large, having a maximum diameter of 13 or 14 feet. The dip is steep and regular, and the greatest depth reached in September, 1915, was about 130 feet. For a depth exceeding 100 feet the gangue of the molybdenite and bismuth appears to be a granite in which the felspars contain much mica, and in which a considerable amount of silicification has occurred.

At a depth exceeding 100 feet the pipe has branched, or split locally, one branch being granitic in character, the other being a small pipe of quartz.

A similar feature to this was observed in A. E. Cooper's pipe in Portion 44, Parish Booroo, County Clive.

The famous Pilot at Whipstick is an occurrence analogous to these.

6. Mount Morgan. No. 34 on the accompanying list. Situated on Portion 100.

This deposit is a large quartz pipe, the diameter, in cross-section, being as much as 15 and 20 feet in places. It outcrops on the highest point of the rugged plateau which overlooks the greater number of Yates' Pipes. The deposit has been worked on the underlie for a distance of 225 feet.

Pl. X (*b*) illustrating the rugged nature of the Kingsgate topography was taken from a point near the pipe under consideration.

7. One and Nine Tunnel or No. 5. No. 5 on the accompanying list. Situated on Portions 1 and 9, hence the local name of the pipe.

This is one of the important deposits of the district. It outcrops in the northern portion of the Kingsgate area [Map], and it was one of the deposits worked in the earlier days of the field. It is a quartz pipe with several important branches. Near the surface it had a gentle inclination towards the claystone contact with the granite, so gentle indeed that, in a distance of 160 or 170 feet along the underlie, the vertical depth reached barely exceeded 30 feet (Pl. XII [*a*]). This upper portion of the deposit occurred in a portion of the workings known as the Open Cut (Pl. XIII). A couple of branches appear to have been given off here. Thence the deposit pitched steeply for a distance exceeding 70 feet, at which point it became flat for a distance of 50 feet approximately to the face existing in September, 1915. Several branches have been given off at this lowest level, as illustrated on Map 4, where C is one branch 6 feet high and 4 feet wide, horizontal in direction as far as worked, but which may be expected to have an upward inclination at some point further along. A is a branch about 5 feet in diameter which left the main pipe and rose to the west at an angle of 45 degrees to the horizontal. This branch appeared to die away at a distance of 35 feet from the main pipe. The largest branch, however, so far as at present known, left the pipe a few feet from the bottom of the shaft. It rose almost vertically, and at a height of 50 feet above the point of departure it was only about 10 feet from the main pipe. Here it was almost 15 feet in diameter, but within a few feet beyond this point it appeared to die away into the granite roof. See also in this connection the remarkable disappearance of the Pilot and No. 2 pipe at Whipstick.

The main pipe is very large, having larger measurements in cross-section at the bottom of the shaft of 25 feet x 15 feet. It appears to be of great size also in the most recent workings. The gangue is quartz, white and black in colour, both well crystallised, cavernous and compact or jointed, and containing both bismuth and molybdenite.

The deposit in the lowest workings has an appearance quite as promising as it had nearer the surface.

[*Photo E. F. Pittman.*]

No. 1 and 9 Pipe, Kingsgate.

A plan and vertical section of the general direction of the pipe has been reproduced from measurements secured by Mr. Leo Cotton, Acting Professor of Geology at Sydney University. Plate XIII, from a photograph by Mr. E. F. Pittman, illustrates the old workings in the end of the open cut.

8. Reef Blow. No. 51 on accompanying list. Situated in Portion 40 near the south-eastern corner; about 100 yards from the claystone, and dipping towards them at a low angle.

The pipe is of white quartz in the main. Its diameter is about 6 feet and it has been followed for a distance exceeding 100 feet on the underlie. The main pipe was followed for 60 feet from the outcrop at an angle so low that the greatest depth reached was only 12 feet. Thence the pipe was followed in a direction almost vertical for a distance of 30 feet approximately; thence it was followed in a westerly direction without an appreciable dip.

At a depth of 12 feet from the surface the pipe branches into three, one rising steeply to the south towards the surface, one rising to the surface in a westerly direction in a distance of 60 feet approximately, and another rising to the surface in a direction west-north-west within a distance of 60 feet (Fig. 14). Molybdenite and bismuth are the minerals mined.

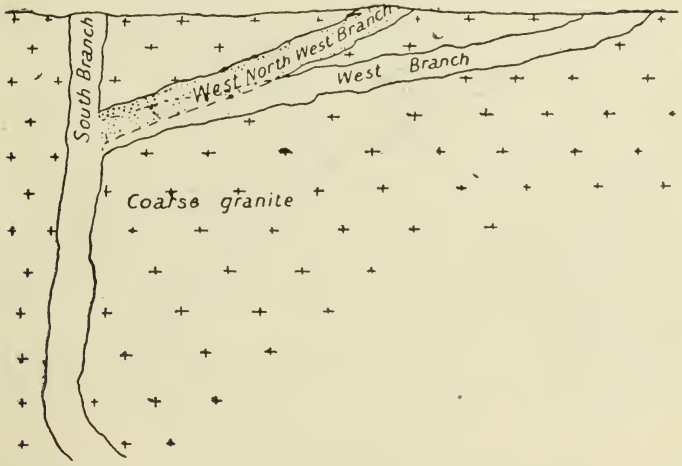


Fig. 14.

The Reef Blow, Portion 40, Parish of Kingsgate, County of Gough.
Diagram illustrating the branching of a quartz pipe near the surface.

9. Tin Shaft or Pipe, or Water shaft. No. 7 on accompanying list. Situated on Nos. 1 and 9 Portions. The pipe is of granite and quartz, with a diameter of 6 feet and with a vertical dip. The total depth worked is about 40 feet.

The pipe is interesting on account of the tin which occurs in it, and because of the fact that this deposit was one of the earliest prospected at Kingsgate.

Although the granite mass containing the pipes is not a tin granite typically, nevertheless in one little corner, namely, Lancaster's blocks (*see* Map) a small area of aplitic, euritic, or tin, granite is wedged between the coarse molybdenite granite and the claystone.

10. Twenty-Five North. No. 13 on accompanying list. Situated on Portion 100.

This is an important deposit. It is very large, being 25 feet across in places. It has been followed along the underlie for a distance exceeding 500 feet, with a vertical depth exceeding 240 feet, nevertheless at the face, in September, 1915, the pipe was large and of promising appearance. At depths between 400 and 500 feet, the measurements of the pipe were as much as 25 feet diameter.

For 300 feet from the surface, as measured along the underlie, the inclination of the deposit was not pronounced, whereas from 300 feet downwards the slope was fairly steep. A vertical shaft has been sunk to facilitate mining operations [Pl. X (*a*)].

Several branches, varying in length from 25 to 50 feet, and inclined steeply in an upward direction, occur between the surface and a depth of 300 feet.

The gangue is the usual white and black quartz of Kingsgate, which occurs both crystallised and massive, cavernous and compact, jointed and brittle and passing into the granite walls by the intermediate stages of granite highly silicified and felspars highly sericitised.

The yield of bismuth from this pipe has been large, and it is being worked now both for bismuth and molybdenite.

The plan and vertical projection of the main directions of this pipe have been reproduced from measurements supplied by Mr. Yates (*see* Map). Pl. XVI illustrates the more recent work done below the 300-feet level, from measurements by Mr. Leo Cotton.

11. Wolfram Pipe.—Known as Old 26 or Little Tunnel. No. 10 on accompanying list. Situated within Portion 100.

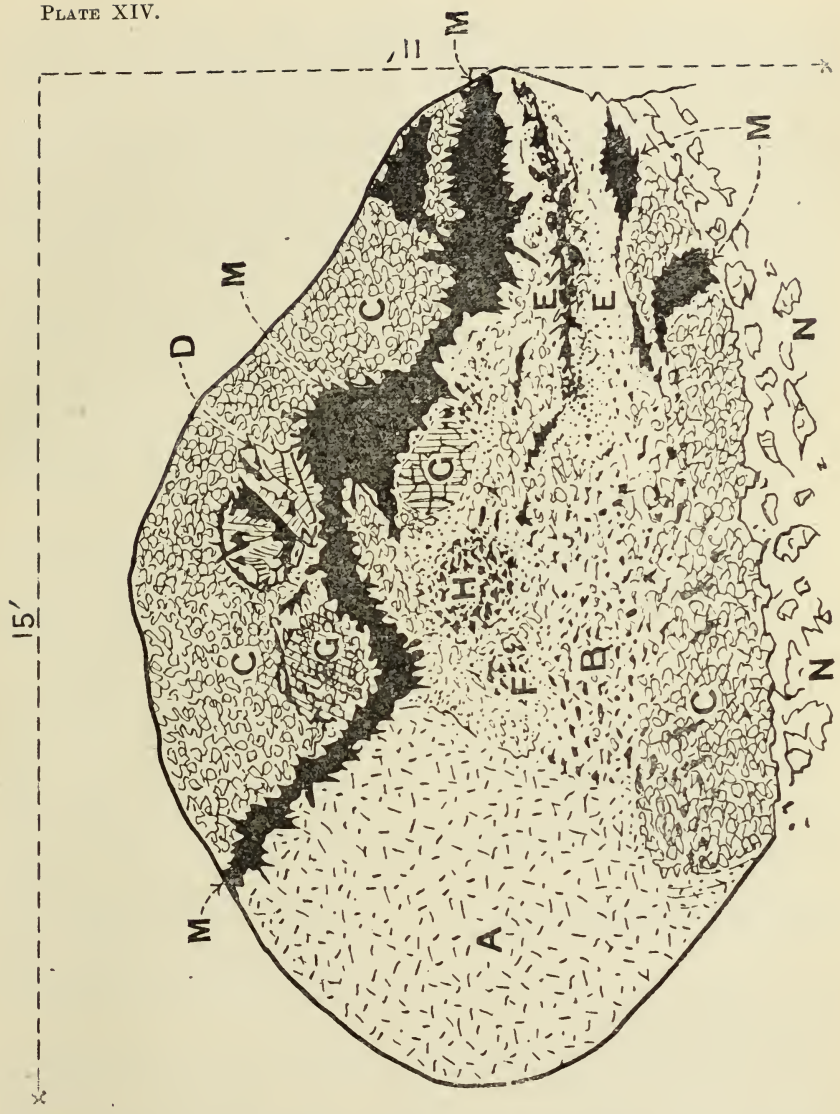
This deposit is interesting mainly from the fact that it was the first one to be prospected at Kingsgate, the Tin Show apparently being the second to be worked. It was worked in the first place as a large open cut. At a later date a tunnel was put into the hillside to reduce mining expenses. The average inclination of the pipe is not great, being about 26 degrees. The deposit is large, having a diameter of 12 feet approximately, and the depth is 100 feet, as measured along the underlie.

The gangue consisted, in great measure, of massive white and grey quartz containing a considerable amount of massive wolfram and arsenical pyrites.

B. Block No. 45.

1. Old 45, known also as Sachs' Pipe.—In the early days of the field this pipe was not secured by the Kingsgate Bismuth Company. At a later date it was found by another body of propectors and worked for bismuth. At a date still later Mr. Henry Marshall, along with others, worked this claim, but abandoned it because of its molybdenite contents, which hindered the operations of the miners in dressing the ore for its bismuth content. In 1902 it was taken up by the late Mr. Valentine Sachs, who found a great expansion of the pipe below the older workings. From the chamber excavated therein, which is said to have exceeded 50 feet in length and 20 feet in diameter, he won many tons of molybdenite. A complete record was not furnished by Mr. Sachs to the Department of Mines, but it is reported, however, that the value of the molybdenite and bismuth won from the pipe at this point considerably exceeded £30,000. A few years later the pipe was "lost," and a search was made in all directions for its continuation. Mr. Sachs appeared to be unsuccessful in his attempts to recover the pipe, and at a later period the lease passed into other hands, a new company, the Glen

PLATE XIV.



Sketch Plan of Sachs Molybdenite pipe, at present face 250 feet deep on underlay.

A—Coarse acid granite (country) showing seritisation of felspars and development of flakes and scales of molybdenite.
B—Still more altered granite passing insensibly on all sides into tight granular quartz with flakes of molybdenite.
C—Hard granular quartz, showing traces of felspar, and considerabie development of molybdenite.
D—Parch of quartz crystals, showing molybdenite and bismuth patches, both between and inside quartz.
E—White massive quartz developing from sericite.
F—Hard, tight, glassy quartz, developing from sericitised granite (A).
G—Massive quartz developing from hard granular cairngorm.
H—Granite, almost completely altered to sericite. The contours of the original felspars still showing.
M—Masses of molybdenite in large tables, foils and aggregates. (Bismuth associated with MoS_2, as sulphide and native).
N—Broken ore.

NOTE.—This peculiar sericitisation and silicification of granite characterised the pipe all the way down; also all the other Kingsgate pipes; also the Timbarra and Pheasant Creek pipes.

Innes Molybdenite and Bismuth Syndicate, being formed to work the deposit afresh. Mr. Hagen, manager for the company, made a careful examination in directions generally towards the claystone or slate in the vicinity. He actually cut the claystone in one place within a distance of 18 feet from the "hanging wall" of the deposit near the base of the old rich chamber. The floor of the chamber was then cleaned and a bunch of quartz was exposed therein about 18 inches in diameter, according to the statement of Mr. Hagen. This was followed in a vertical direction for a depth of 30 feet, the size of the deposit being 4 or 5 feet in diameter, at a depth of a few feet below the chamber. Thence it was followed easterly for a distance of 25 feet along a very slight slope. At this point the pipe was still small, and it was followed thence in a vertical direction for a distance of 15 feet. Beyond this it was followed in an easterly direction along a negligible slope for a few feet, where it appeared to split into two, each branch being small, one directed towards the north-north-east at a steep angle, and the other towards the east first and then south-east at a steep angle.

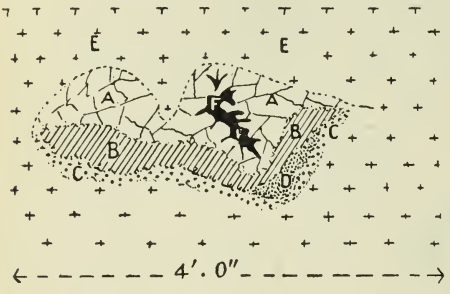


Fig. 15.

Sketch of face in No. 45 Pipe, Kingsgate, at a depth exceeding 300 feet.

A—Coarse brittle white quartz.
B—Coarse cavernous granular quartz.
C—Coarse granite with felspars altered to fine mica.
D—Soft hydrous mica.
E—Coarse siliceous granite and quartz.
F—Coarse molybdenite in white quartz.

The workings are approached by a tunnel about 100 feet in length, which intersects the pipe at a depth of 30 feet approximately below the outcrop in a vertical direction. The pipe in this upper portion dipped at an angle of 45 degrees, thence, for a distance of 50 feet, in a direction south-south-east it had a negligible slope, while beyond this division for a distance of 100 feet or thereabouts, the pipe maintained a direction, generally easterly, at a slope about 1 in 2 (26 degrees). In the lower portion of this underlie the great chamber was excavated, from which the rich body of molybdenite and bismuth was won.

The pipe appears to be associated with joints containing molybdenite; indeed, joints possessing molybdenite contents are common features in association with the pipes of Kingsgate. The frontispiece and Pl. XIV illustrate various features of interest in this pipe, Pl. XV being a sketch made on the spot from measurements and observations taken at the face in 1905. Fig. 15 illustrates the appearance of the face in September, 1915, at a depth about 80 feet below that seen in 1905. From this sketch it may be seen that the company appear to be on a pipe which is promising in appearance, from the point of view of its mineral association, although it is small in cross-section. The depth of the workings, as measured along the underlie, must exceed 300 feet. It would be advisable to continue sinking, for it is almost inconceivable, from a general knowledge of the Kingsgate deposits, that a pipe such as the Old 45 should die away thus suddenly, which, in the first place, had produced so much ore of good quality; which, in the second place, although small in the face, yet exhibits all the characters

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Plate XV.

Goodwin's Pipe. Sachs of Kingsgate Property.

of a good pipe, namely, that it is composed of brittle quartz, containing a considerable amouut of molybdenite as coarse flakes and as masses, with brown quartz underneath the white brittle quartz, and with patches of soft mica below this again, all being near the claystone contact; and which, in the third place, is only one of a group of fine pipes, all intimately related, and none of which have been proved to die away, and some of which are still very large and rich at depths as great or even greater than that reached in the Old 45.

Treatment Plant.—This is said to be the most expensive and the best plant on the field. Its cost is reported to be £1,400 approximately. It was being erected during September, 1915, and only 100 yards or thereabouts further upstream on the Yarrow Creek from Sachs' old plant.

The description of Yates' Upper Plant would stand for that of the one under consideration (p. 9). The question of oil flotation does not appear to have been considered seriously by any one of the companies working the Kingsgate deposits, the finest group of molybdenite deposits known up to the present in New South Wales.

2. The Monkey Shaft.—This is a very interesting occurrence, which suggests that joints or planes of weakness have had much to do in the formation of the molybdenite pipes.

The deposit was worked as a true vein for a length of 45 feet, the jointed white quartz of the fissure varying in width from 2 feet to 2 feet 6 inches. The vein was followed in a vertical direction to a depth of 25 feet; thence it was followed in a westerly direction for a distance of 40 feet, the slope not exceeding 1 in 5, and the thickness of the vein varying from 3 to 4 feet. The length of this flat portion of the vein was about 50 or 60 feet. Beyond this point it was traced in a direction almost vertical for a few feet, thence, according to Mr. H. Marshall, it was worked as a pipe exceeding 8 feet in diameter on a steep slope.

In September, 1915, this lower portion of the workings was full of water drained by an adit tunnel driven to facilitate mining operations.

(*C*) *Sachs of Kingsgate Syndicate.*—This company holds M.P. 4 of 1½ acres approximately, containing both the Wet and Goodwin's Pipes, M.L. 14 of 1 rood 39 perches, on which is situated the treatment plant, and a Mineral Prospecting Area of 40 acres approximately.

1. Goodwin's Pipe, situated in M.P. 4 on road between Portions 41 and 45. (*See* Map.)

The pipe is of quartz and is worked for molybdenite and bismuth. It is of considerable size and has been worked to a depth of 200 feet. The accompanying figure (Pl. XVI) illustrates the plan and section of the main directions of the pipes. The measurements are by Mr. Leo Cotton.

Pl. XV illustrates the appearance of the mouth of the pipe and the method of winning the ore, namely, by hand windlass at the end of an open cut excavated in the pipe.

There was no appearance of "dying out" at the lowest point of the workings seen in September, 1915.

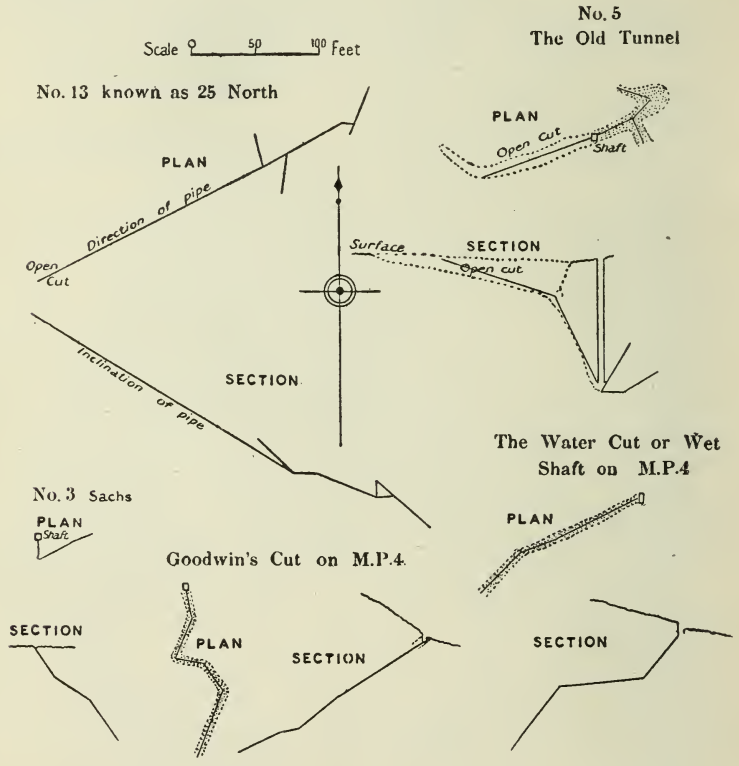
2. Prospecting Area.—An area about 40 acres in extent, consisting of old M.L. 50 and an area lying immediately to the west of Portion 44 and south of M.L. 50 (*see* Map).

Several quartz pipes containing bismuth and molybdenite occur within the subject area, all of which appear to be worthy of being prospected. The positions of these are indicated on the accompanying map of Kingsgate by the letters F, G, H, I, and J.

No. F is known locally as Potter's Claim. Prospecting has been conducted at the surface only, and it is impossible, at this stage, to make any forecasts as to its future.

No. G, or the "Reef Blow," is peculiar, inasmuch as it occurred as a long annular mass of quartz having a gentle slope near the surface, and there containing excellent prospects of molybdenite, nevertheless after being prospected to a shallow depth it appeared to rise in one place to the surface in the form of a true vein. It is probable that this deposit may be traced into a pipe.

PLATE XVI.



General directions of various pipes at Kingsgate—from measurements by Leo Cotton.

No. H, or the Giant Blow, is a very large deposit containing much quartz in the form of huge crystals with double terminations in the form of pyramids. The vertical depth reached by prospecting operations is 35 feet approximately, but this work was done some years ago. The diameter of the pipe appears to be about 20 feet. The minerals contained in the quartz are bismuth and molybdenite.

3. Wet Shaft, or Road Pipe (Sachs of Kingsgate). M.P. 4, lying between Portions 41 and 45.

This is a large quartz pipe containing bismuth and molybdenite. The diameter at the face in September, 1915, appeared to be about 8 feet. The general indications of the appearance of the pipe and its mineral association are those of an important deposit.

According to Mr. H. Marshall, manager in 1915 of the Sachs of Kingsgate property, the mine has been a good producer of bismuth and molybdenite. In September, 1915, no rich masses of mineral were to be seen in the face, but in Kingsgate the miners pay little heed to local impoverishments, or to local constrictions, of the pipes themselves, inasmuch as the deposits vary from point to point both in size and richness of contents.

In this pipe, as in others at Kingsgate, the bismuth appears to occur more abundantly on the "footwall" in a granular, cavernous, but tough quartz of brown colour, while the molybdenite appears to be arranged in a higher zone.

Fig. 16 is a sketch of the general arrangement of the minerals in the face in September, 1915. The plan and section of the general direction of the deposit have been reproduced from measurements by Mr. Leo Cotton.

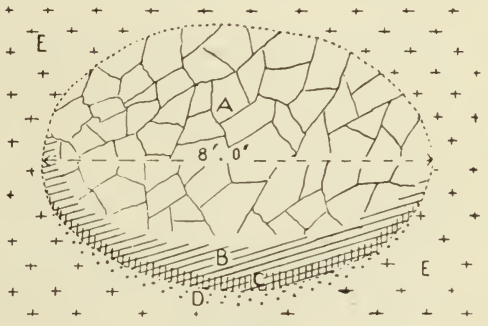


Fig. 16.

Sketch Plan in the Wet Shaft, at a depth of 200 feet.

A—Coarse brittle white quartz, crystallised or massive, containing large vughs, and some molybdenite.
B—Cairngorm crystallised or massive with molybdenite and a little bismuth.
C—Brown granular and cavernous quartz with rich bismuth and a little molybdenite.
D—Coarse granite with felspars partly altered to mica.
E—Coarse siliceous granite.

Treatment Plant.—A plant exists on M.L. 14 on portion 45 for the treatment of the bismuth and molybdenite ore. It is a type somewhat similar in cost and efficiency with those described on pp. 9 and 10 as belonging to Mr. Yates.

(*D.*) *Speckhardt* (*Pauline*) *and Party.*—M.L. 1 of 30 acres. Parish Kingsgate. Government aid has been granted to work two pipes on this area.

The various deposits worked on this lease are shown on the accompanying map of Kingsgate. The pipes indicated by the letters A, B and C on the map are known as Nos. 1, 2 and 3 respectively by the miners, but they are indicated by letters on the map to prevent confusion with those marked 1, 2 and 3 on Yates' Blocks to the north.

No. A (*No.* 1).—A quartz pipe containing bismuth and a little molybdenite. The diameter is nearly 6 feet. It is approached by a tunnel driven in the steep hillside. From the outcrop the pipe was followed east for a distance of 75 feet at an angle of 40 degrees approximately. Thence it was followed in a direction south-south-east for 12 feet on a negligible slope, and beyond that to the face at a distance of 17 feet on a very steep slope. The indications in the face exposed in the face during September, 1915, were not very encouraging.

Plate XVII illustrates the association of Nos. A and B pipes in outcrop.

No. B (*No.* 2).—This is a quartz pipe containing bismuth and molybdenite. Only the upper portion of this pipe was accessible in September, 1915. Near the surface a "dropper" associated with abundant soft mica has been prospected, the descending branch or "dropper" appearing to pass into a wide joint or vein of mica and altered granite. From the outcrop the main pipe was followed in a south-east direction for a distance of 100 feet, approximately, at a steep angle.

Rich stone was worked at one place in the mine, and a parcel of ore, about 40 tons in weight, won from the deposit is expected to yield at least 1½ tons of bismuth and molybdenite after losses by treatment.

The outlook for this pipe, as judged by the appearance both of the upper workings and the class of ore lying at the surface, is decidedly encouraging.

No. C (*No.* 3).—A quartz pipe containing bismuth. The pipe is nearly 100 feet deep as measured along the underlie. The face at the bottom workings was in a local constriction during September, 1915. The indications of the more superficial workings were favourable for the continuation of the pipe with increased depth.

(*E.*) *Lancaster's Areas.*—Between the outcrop of the famous Black Pipe and the claystone, a small wedge of granite occurs which is fine in texture and which possesses the general characters of a tin-wolfram granite.

The Black Pipe was worked for a distance exceeding 310 feet on the underlie and, according to Mr. Lancaster, the pipe was worked within a few yards of his P.M.L. 1, and he is hopeful of picking up either the continuation of this or another deposit.

He holds three areas (*see* Map)—one of 5 acres, being M.L. 16 of 5 acres adjoining Portions 1, 9 and 10: M.L. 15, 3 roods, over road between Portions 100 and 104; and P.M.L. 1 of 4 acres within Portion 104.

In this sandy granite Mr. Lancaster has prospected some small veins of quartz reported to contain bismuth and molybdenite. At the time of my visit in September, 1915, the prospecting holes sunk by Mr. Lancaster were about 10 feet deep. Nothing of importance has been disclosed as yet by the prospecting operations.

Marshall's M.L. 3, 10 acres, Parish Kingsgate, County Gough.

This is indicated on the accompanying map of Kingsgate as adjoining the Old 45 Block, Portions 41 and 44, and M.L. 1. The block is long and narrow and the great granite and claystone junction sweeps throughout the length of the lease. Nothing of importance has been reported to the present time.

O'Donnell's Lease.—E. D. O'Donnell holds a dredging lease of the bed and banks of Yarrow Creek, being Portion M.L. 2 of 5½ acres. Mr. O'Donnell's intention was to attempt the recovery of a proportion of the bismuth and molybdenite tailings which had been discharged in the past in great quantities from Sachs' mill on M.P. 4 or M.L. 45.

Murphy and Wilson's Claim.—M. Murphy and R. Wilson took up a mineral prospecting area of 40 acres adjoining Portion 24 on the north.

Ruming's Claim.—E. J. Ruming holds tenement No. 76, Glen Innes, being a Mineral Claim of 3 acres for the purpose of working molybdenite and bismuth.

Cahill's Claim.—Michael Cahill holds an area of 10 acres under an Authority to Enter. This area had been prospected already for molybdenite and bismuth by several small parties of miners.

Several outcrops on Portion 92 have been worked, but at present no work is being done on this portion.

Nos. 1 and 2 Pipes (Nos. A and B on map). Pauline Speckhardt's Lease, Kingsgate.

(F) Yarrow Creek Deposits.

The Dodger Claim, known also as Maurer's Claim.—P.M.L. 1 of 1 acre, and Authority to Enter of 17 acres, approximately, surrounding P.M.L. 1, Parish Yarrow, County Gough, and about 2 miles south of the Kingsgate mines and apparently along the same great granite margin in proximity to the claystone.

Occurrence.—Several quartz and granitic pipes in sandy granite and containing bismuth and molybdenite.

The accompanying sketch map, compiled from notes supplied by Mr. G. P. Maurer, shows the association of the granite and the claystone, and the proximity of the pipes to the contact of the two rock types.

In September, 1915, the mining workings were filled with water, and no inspection of the workings themselves was possible. A few large heaps of material were lying on the surface alongside the shafts and open cuts. These heaps consisted of quartz, both massive and crystallised. Many of the crystals were terminated at each end with pyramids. Silicified granite in abundance had been mined in the shafts. Molybdenite, as abundant flakes, was scattered throughout the stone heaps. All these were indicative of a prospecting area of promise.

In the absence of a personal examination of the underground workings, the following notes are reproduced here based upon statements by Mr. Maurer.

Mr. Maurer states that the slate and granite junction is continuous to Kingsgate in a direction north-east, a distance about 2 miles. This junction appears to be traceable for several miles to the south-east.

On the accompanying sketch map (Fig. 17) the deposits are indicated as Nos. 1, 2, 3 and 4. No. 1 was 30 feet long and 8 feet wide at the surface. This deposit has been proved to a depth of 50 feet. Bismuth and molybdenite are exposed in the bottom. From this deposit Mr. Maurer took 7 cwt. 46 lb. of concentrate averaging 95 to 97 per cent. molybdenite.

The No. 2 has been prospected to a depth of 10 feet or thereabouts and molybdenite ore is scattered over an area about 12 feet long and 8 feet wide at that depth.

The No. 3 deposit appears to be a pipe, which has been prospected to a depth of 60 feet. At the bottom it is about 8 feet long and 6 feet wide, showing much brown granular quartz with flakes of molybdenite scattered somewhat plentifully through it. According to Mr. Maurer a ton of molybdenite has been won from this deposit. The exact amount is not known as molybdenite was won here by another party in 1902, but no written records were kept by these earlier prospectors.

No. 4 Pipe, according to Mr. Maurer, has been prospected to a depth of 15 feet, at which depth the ore-bearing material occupies an area 10 feet in diameter, in which bismuth and molybdenite occur within quartz which occurs in patches through altered granite. This pipe lies about 50 yards distant from No. 2.

In 1916 aid from the Prospecting Vote was granted to Maurer and party to sink.

Production.—1902, unknown; 1914, unknown; 1915, concentrate sold for £115.

Additional Areas at Yarrow Creek.—Deposits containing bismuth and molybdenite have been worked on Portions 101 and 102, Parish Yarrow. Information supplied by Mr. Warden Perry.

Payable deposits are said to exist on Portions 20, 21, 22 and 23, Parish Yarrow, in respect of which gold only is reserved to the Crown. Information supplied by Mr. Warden Perry.

Future of the Kingsgate Pipes.—The greatest length of the workings in any one pipe at Kingsgate exceeds 500 feet, but even at this depth the pipe worked does not appear to be different, in any pronounced degree, from its upper portions. This remark applies equally to the general size of, form of, and mineral association within, the pipe. Other pipes, such as the Black, the One and Nine, the Forty, and the Old 25, exceed 250 feet in length as

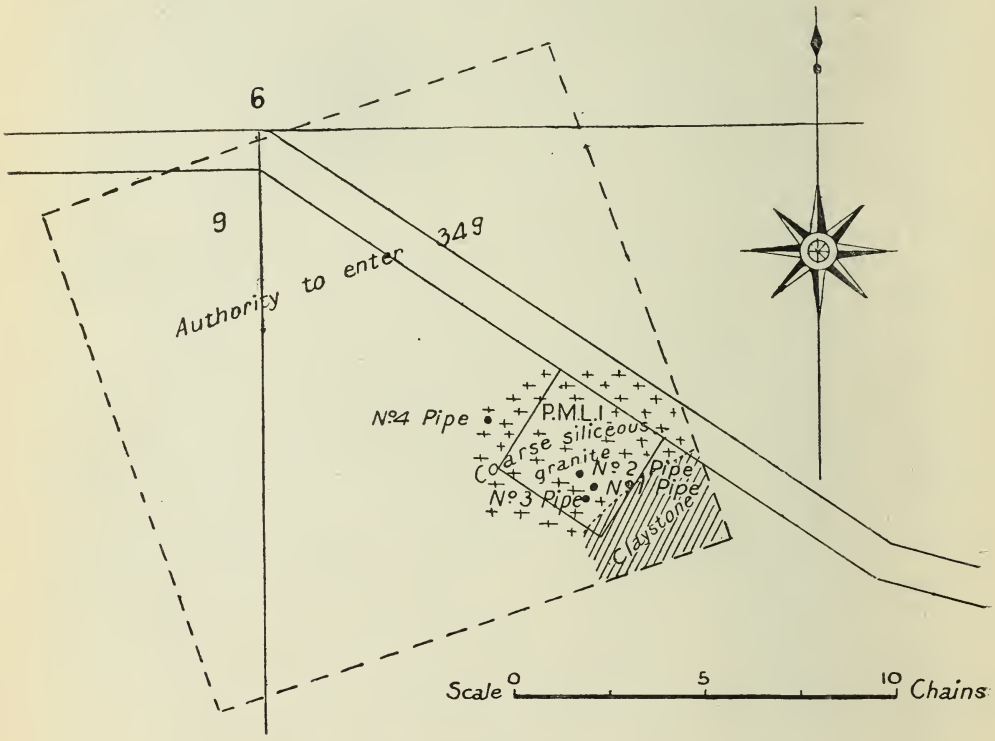


Fig. 17.
Parish of Yarrow, County of Gough.
Sketch May of P.M.L. 1 or Maurer's Claim.

worked, and their appearance, at the lowest workings, is such as to suggest an indefinite continuation of their pipe-like nature and their mineral association.

In this connection it may be stated that the general geological conditions at Kingsgate molybdenite and bismuth mines are very similar to those obtaining at Whipstick and Wolfram Camp. At Whipstick the lowest workings are nearly 450 feet vertically below the highest outcrop in the same branched pipe, and the pipe is very large in the bottom workings, and the ore grade, though lower there than in some other portions of the mine,

may be only a local impoverishment. In Northern Queensland, Murphy and Geaney's shaft exceeds 300 feet in vertical depth, while that of Leisner's Block is still on rich ore at a vertical depth exceeding 460 feet.

In the second place the Kingsgate pipes appear to follow directions approximately parallel to the intrusive contact-surface of the granite, and as such the conditions of ore deposition at depths up to 500 feet, or even more, along the underlie may be considered to be somewhat similar to those obtaining nearer the surface. In the third place the native bismuth, as also the bismuth and molybdenite sulphides of the deposits, appear to be primary and not secondary in character, and, as such, the ore deposits may be expected to continue downwards for distances unknown at present. In this connection attention is directed to the notes in the next paragraph.

At a certain depth from the surface, however, the cost of working the pipes would be prohibitive, even supposing the mineral content of the ore to remain the same as nearer the surface. With regard to this question of the content of bismuth and molybdenite in the deposits at a depth it is the opinion of the Writer that the average tenor in value of such content will be found to suffer a gradual decrease. This belief is based on the inference that the deposits have been precipitated from heated vapours escaping from a region of great pressure and heat to one of less pressure and heat. Anyone who has examined a smelting furnace has noticed the deposition of the sulphur, arsenic, bismuth, and other volatile material at varying distances from the source of heat, and they have noted that from some point of maximum deposition away from the furnace the deposits of this particular mineral become less and less as the furnace itself is approached, not because the mineral under consideration has never been in the furnace, but because its vapour was under pressure and heat of such intensity that it was driven past this point to one of decreased pressure and heat to suit the conditions of precipitation. And these remarks would obtain indifferently whether the precipitation should take place in open places or as the result of replacement, provided that the vapours could move in a direction away from the pressure. As the pipes are followed it may be expected that the bismuth and molybdenite, therefore, would decrease gradually in amount while other minerals may be expected to be found, minerals which might be precipitated closer to the natural hearth supplying the initial pressure and heat.

For such a group of mines, for example, as Yates' freehold, there is a fine chance to apply modern methods of mining and treatment. These mines are not under many petty and individual controls, in which each holder might be expected to do nothing himself beyond asking an exorbitant and altogether prohibitive price for his particular pipe. In this particular property there are many fine pipes, and there are several prospectors skilled in the peculiarities of the pipes. Vertical shafts could be sunk to facilitate mining operations, and certain pipes, conceivably, might be connected underground, and adits might even be designed to help mining. The ore could be gravitated to a central mill near the Yarrow Creek, the sequence of operations within the mill being facilitated by gravitation, and some form of oil flotation might be adopted for the recovery of the molybdenite.

Kirk's Block. *See* Yetholme.

Kirk's (Zephyrn) Claim. *See* Duckmaloi, under Oberon.

Kirk and Wade's Block. *See* Yetholme.

Kirk and Wade's Molybdenite Mines, No Liability. *See* Yetholme.

KOOTINGAL. *See* Moonbi.

KNOX'S (T. AND P. J.) CLAIMS. *See* Tantawanglo.

KNOX'S VALLEY. *See* Tantawanglo.

KRAWARRIE. *See* Goulburn.

KRITSCH'S CLAIM. *See* Nambucca.

LANCESTER'S (T.) BLOCKS. *See* Kingsgate.

LAURA CREEK DEPOSITS.

The Laura Creek molybdenite deposits occur mainly in Portions 34 and 52 (as also in the vicinity of these portions) in Parish Abington, County Hardinge, and in Portions 66 and 67, Parish Russell, County Hardinge, on and near Laura Station and about 9 miles from the Booroolong or Balderslie deposits.

Each group is contained in a siliceous granite, of the tin or wolfram type, near its intrusive contact with claystone, volcanic ash, and other sediments, of unknown age, but probably Permo-Carboniferous.

This granite has given off long tongues of aplite and pegmatitic material, fine in texture, into the surrounding sediments, and in certain cases in the area under consideration these tongues form large dykes. In one place along the creek, about a mile above the main deposit, a deep and straight-sided gorge has been formed for a length exceeding half-a-mile, by the Laura Creek in cutting its channel within a narrow belt of sediments which lie between two large tongues of siliceous granite.

The granite of these tongues is more siliceous, and of finer texture, than the main mass of the granite, and the felspar and quartz which constitute the greater portion of the prolongations are so intimately associated as to suggest that they have crystallised, or separated out, almost at the same time. Molybdenite in small thin flakes is scattered sparingly throughout the tongues and it appears to be part and parcel of the rock, and it has separated out as tiny flakes or as small nests of very thin flakes.

Spencer's Claims.—This feature is well illustrated in the deposit facing Laura Creek and lying immediately to the west of the southern portion of Portion 52, or W. J. Frame's Crown Lease. The granite tongue here is from 100 to 200 yards in width, and forms a very steep bank or spur rising from Laura Creek. In this molybdenite flakes may be found in every square yard of outcrop for a length exceeding 300 yards and a width exceeding 100 yards. The mineral is not concentrated sufficiently, however, to repay cost of mining and treatment of the ore unless rich patches occur, which, however, have not been revealed, nor even indicated, by prospecting operations to date. The hillside, at this point, is scarred with shallow prospecting holes varying in depth from 6 inches to 8 feet or even more. In the opinion of the Writer, it is unlikely that large patches of molybdenite ore will be found here of a degree of concentration higher than that already tested.

Two miles higher up the creek a very siliceous phase of the granite occurs within both the extreme eastern portion of Parish Abington (Portion 67) and the western part of Parish Russell (Portion 66). The main rock here is coarse in texture, but patches of aplite of considerable size and of fine texture form intrusions or segregations in the mass. Tourmaline, in radiating groups of needles, is common and in this aplite a number of tiny quartz veins and small pipes occur, containing individual flakes and small nests of molybdenite. Although a considerable area of this country shows

molybdenite flakes and specks, nevertheless, this mineral does not appear to have been concentrated sufficiently by natural processes to form commercial deposits.

A long and wide quartz vein containing felspar and patches of altered granite occurs between 1 and 2 miles north-west of the Laura Creek outcrops. Very small flakes and specks of molybdenite are to be seen in the outcrops.

Mr. A. S. Spencer, of Neranghi, Barraba, has prospected the areas mentioned above.

Lithgow Blocks. *See* Yetholme.

Little Tunnel. *See* Kingsgate.

Llangothlin.

Thomas Hibbert and Thomas Arundell hold an area of 80 acres within Portions 29, 42, and 43, Parish Llangothlin, County Gough, 40 miles south of Glen Innes, under Authority to Enter.

Information supplied by Mr. Warden Perry.

Locksley. *See* Yetholme.

Lode Hill. *See* Oban.

Logan (W. A.) and Party's Claim. *See* Serpentine, under Guy Fawkes.

Lowe's Claim. *See* Oban.

Lowther. *See* Oberon.

Ludwell's Claim. *See* Goulburn.

Macksville. *See* Nambucca.

Macpherson's Lease. *See* Booroolong.

Main Pipe. *See* Whipstick.

Manildra Deposits.

The accompanying notes have been supplied by my colleague, Mr. M. Morrison.

Held as three Authorities to Enter—one of 10 acres by J. Moore, one of 10 acres by W. J. Higman, and one of 20 acres by T. Lennan, on Portion 181, Parish Manildra, County Ashburnham, about 5 miles north-north-west from Manildra.

The workings examined by Mr. Morrison are said to represent the prospecting operations by J. Moore and party.

> "The country rock is a fine to medium-grained siliceous granite composed mainly of quartz and orthoclase with a little muscovite.
>
> "The molybdenite occurs as small flakes and specks sparsely distributed in a hard glassy quartz. Small crystals of orthoclase were also observed in the quartz. There are two outcrops of quartz which are approximately parallel to each other and which extend for a distance of about three chains in a north-easterly and south-westerly direction. On the northern end of the western outcrop an opening or rough shaft about 10 feet across, and about 14 feet in depth, has been sunk in the quartz. On the eastern side of the shaft a well-defined junction between the granite and quartz is exposed, but the western granite wall was not exposed. The molybdenite occurs as specks and as small flakes in patches throughout the quartz.

"Owing to the very limited amount of prospecting done, it is difficult to determine the exact mode of occurrence of the deposit, but from the sharp line of junction between the granite and the quartz, I am inclined to the opinion they are veins or reefs traversing the country rather than 'pipes' or acid segregations in the granite.

"Whether the occurrence be of the nature of a 'pipe' or a vein, I can see no reason to anticipate an improvement in the value of the ore with increased depth of sinking, unless it be perhaps at spots where a cross-course or a particular 'bar' of country rock intersects the quartz, in which case pockets or bunches of rich ore may be found. . . ."

Mann River.

H. A. McIntyre and D. Murphy hold 40 acres under Authority to Enter over portion M.L. 1, Parishes Mann and The Brothers, at the junction of Yarrow Creek and the Mann River.

Information supplied by Mr. Warden Perry, 1915.

Molybdenite flakes in granite. Prospecting by trenches. No commercial deposits found. (Misc. Mines Papers, 1909–5282.)

Information taken from Mr. L. F. Harper's report, 1909, in Mines Papers mentioned herewith.

Marshall's (H.) Lease. *See* Kingsgate.

Martin's Authority. *See* Wilson's Downfall.

Marulan Deposits. Molybdenite flakes in granite.

Maryland. *See* Wilson's Downfall.

Maurer's Claims. *See* Yarrow, under Kingsgate.

McCanna's (P.) Claims. *See* Dichard.

McDonald and Lee Wing Yuen's Claim. *See* Glen Elgin.

McGauran's Claim. *See* Coronation Mine, under Deepwater.

McIntyre and Murphy's Claim. *See* Mann River.

McKinley's Claim. *See* Booroolong.

McLeod's (J. and S.) Claim. *See* Nambucca.

Merrybindinyula. *See* Bethungra.

Middle Creek. *See* Tingha.

Mole Tableland.

1. *Taylor's Lodes.*—Portions 68 and 71, Parish Bundar, County Gough.

Professor T. W. E. David reported* that "Taylor's veins, on the Glen Creek, three in number. . . . The geological character of the country near these veins is somewhat irregular. Three oval masses of granite, from 4 to 10 chains in diameter, have burst through the claystone at a distance of two miles south of the junction line of the granite and claystone. These dykes of granite are traversed by tin-bearing veins, which continue to be stanniferous as long as they are enclosed in granite, but where the casing rock is claystone, the tin-stone is replaced by mispickel, molybdenite, and probably bismuth.

* Geology of Vegetable Creek. Memoirs Geol. Survey, N. S. Wales. Geology, No. 1, 1887, p. 127. Quoted from J. E. Carne, Tin-mining Industry, 1911, p. 146.

. . . "In the same portion (71), north of the preceding vein, is another vein 1 foot wide, striking 21 degrees north of east and south of west. The vein consists of quartz and mispickel, with molybdenite and probably bismuth. The casing is claystone. This locality is very promising, and is worthy of being prospected, especially near the main gossany vein."

2. *Walker's Claims.*—M.L. 6 of 40 acres and a Prospecting Area of 80 acres adjoining the lease to the north-east, both within Parishes Haystack and Dumaresq, County Gough, near the Gulf.

The area being prospected occurs on the lower slopes of Haystack Mountain, a rugged mass of quartz-porphyry and sandy granite rising abruptly to a height exceeding 1,500 feet from the Beardy River, near its junction with the Dumaresq River. It is situated poorly as far as transport is concerned, being connected with Deepwater by rough hilly road (to Strathbogie) for 57 miles, with Tenterfield by very poor and hilly road about 50 miles in length, and by good road for 77 miles from Inverell by way of Bonshaw.

The granite containing the molybdenite is the usual tin or tin-wolfram type, and the deposits prospected are small quartz veins containing patches of molybdenite, wolfram, bismuth, and silver-lead ore, near the intrusive contact of the sandy granite with quartz-porphyry. The molybdenite, which is the mineral of greatest commercial importance in the areas prospected to date, is said to have been discovered by Mr. D. R. Walker.

The quartz veins, though narrow, are of considerable length and their general strike is about N. 50° to 55° E., the dip is almost vertical, and the quartz is not detachable readily from the enclosing granite. The molybdenite is distributed irregularly throughout the veins in thin flakes.

Very little work had been done in the way of prospecting at the time of my visit in September, 1915, beyond the sinking of shallow pits and costeans. This applies more especially to the area occupying the lower slopes of the rough mountain and the river flat below, namely, M.L. 6. In this 40 acre lease a small open cut had been made to a depth of 10 or 12 feet, from which a few fair specimens of molybdenite had been obtained together with a little bismuth associated with arsenical pyrites.

In the 80 acre prospecting area, and which is situated higher up the rough mountain side, a number of holes have been sunk, all showing a moderate content of molybdenite as small thin flakes in a couple of long but narrow outcrops of quartz veins. About a mile from the river a shaft had been sunk on a narrow vein for a depth of 21 or 25 feet in September, 1915. Small flakes of molybdenite were associated at the bottom with quartz, earthy material, and with arsenical pyrites said to be rich in silver sulphide. This shaft was being sunk during my visit. The vein, according to Mr. Walker, is continuous with the vein prospected in the 40 acre base. This may be so, but there is no sign of it at the surface within the large and wide mass of quartz-porphyry which separates the sandy granite intrusions along the line of the quartz veins, and it is probable that the vein has not been formed in the porphyry, but is continuous in the granite beneath the porphyry inclusion or pendant.

The molybdenite ore itself, if taken over a working width, is low in grade, and mining costs would be very high because of the hardness of the granite and the nature of the vein. The distribution of the molybdenite is patchy. Several small veins were seen, but they are too far apart to be worked as one mine, or from one shaft.

The wolfram ore observed occurs as small patches in narrow veins in the granite.

Production, if any, not known.

In my opinion the claims are adapted for working by a very small party of prospectors employing very simple and inexpensive machinery to concentrate the molybdenite and wolfram.

3. *Watkins (E. C.) Claim.*—Prospecting area, Parish Binghi, County Clive, in Torrington district and 19 miles west-north-west of this village. According to Mr. George Smith, Inspector of Mines (P.B. Papers, 15-4752 Mines), "The molybdenite is disseminated through very hard granite in small specks, but the quantity is very limited and there is no indication present that would point to an improvement in value in depth." Aid was requested from the Prospecting Vote to sink 50 feet upon the deposit, but in Mr. Smith's opinion "the prospects were not sufficiently favourable to warrant the cost of sinking in such very hard ground."

The Moonbi Deposits.

In the Moonbi district a series of Devonian sediments has been intruded by a coarse and dark granite containing abundant hornblende, black mica, and sphene, the rock being porphyritic with large crystals of felspar. This dark granite appears to have been intruded, in turn, by octopus-shaped masses of tin granite, fine and sandy in nature. The coarse granite, containing much hornblende and other dark minerals, and which forms such an important feature in the Moonbi district, will be referred to hereafter as the "dark granite." With the Moonbi are grouped the neighbouring Attunga deposits.

A. Attunga Group.—These occur, in the main, in Portion 60, Parish Gill, County Inglis, about 20 miles from Tamworth by road and track. The country is very rugged and mountainous, the dark granite forming an immense escarpment about 1,800 feet in height, from which the sediments have been stripped by the action of the weather and the streams.

The molybdenite is said to occur as scattered flakes in quartz veins traversing the granite near its intrusive contact with the sediments.

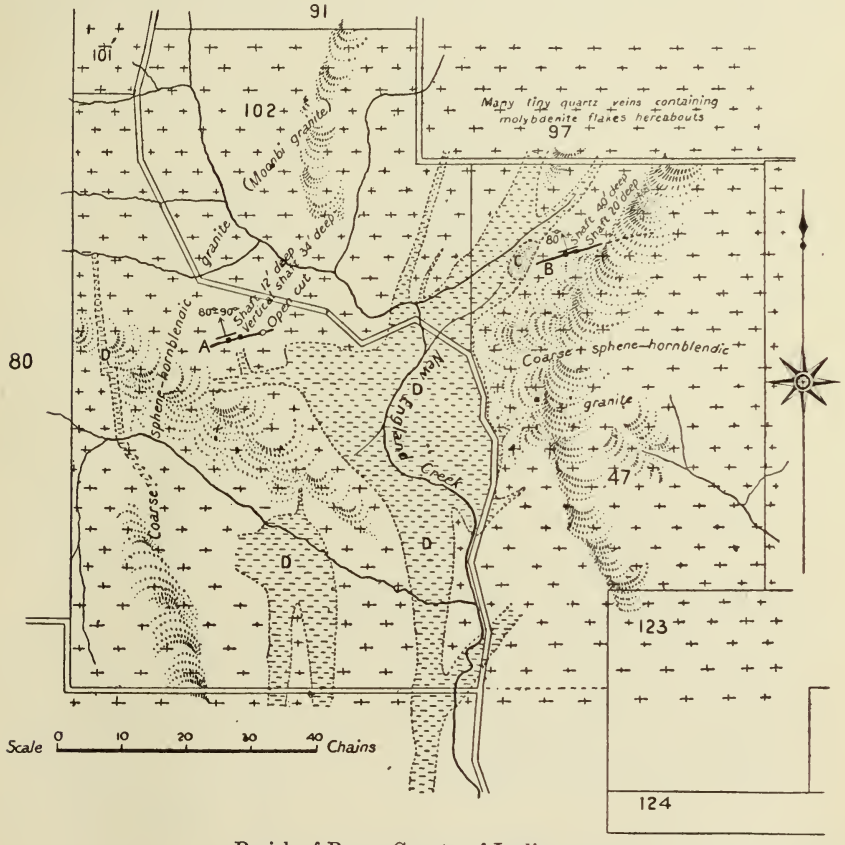
B. Moonbi Group.—These consist, in the main, of true veins and pegmatitic segregations carrying molybdenite. The veins have definite strikes and dips, and they may occur indifferently in either the tin granite or the "dark granite." The first-mentioned of these granites is very siliceous and sandy, and is related to the aplites. The older "dark granite" appears to be related in some intimate manner with the sphene granite of Tenterfield, Wilson's Downfall, Sandy Flat, and Malarra, in northern New England. It has intruded the sediments of the Tamworth district in great swelling curves whereas it, in turn, has been intruded by the tin granites in the most intricate manner (Pl. XVIII), with the production of knots and masses of the tin granite from which numerous dykes and tongues radiate. The margins of the central knots and the tongues or dykes, in places, are pegmatitic, containing flakes of molybdenite scattered throughout them.

The peculiarity of these Moonbi occurrences lies partly in the fact that the quartz veins occur indifferently in the intruding aplite and intruded "dark granite," and partly in the unusual association of the molybdenite with scheelite and copper pyrites in a couple of the veins. Another point of interest is the association of aplite and lamprophyre dykes with certain of the veins.

1. Betts' Deposits.—Held as three Authorities to Enter by T. Betts, one of 5 acres in Portion 182, one of 5 acres in Portion 178, and one of 10 acres in Portion 139, all in Parish Moonbi, County Inglis.

The country is composed of "dark" and "sandy" granites, and is rugged and mountainous. The molybdenite occurs both in small quartz veins and in pegmatitic segregations on a ridge about 800 feet in height overlooking Moonbi, and distant about $2\frac{1}{2}$ miles from the railway station.

PLATE XVIII.



Parish of Perry, County of Inglis.

A—Quartz vein almost vertical varying in width from 4 to 9 inches.
B—Quartz vein varying from 2 to 20 inches wide.
C—Finely-textured pegmatitic granite with molybdenite flakes.
D—Finely-textured aplite (Tin-granite).

The veins occur mainly in the sandy granite, but they extend in a slight measure into the dark granite. The pegmatite with molybdenite occurs within the aplite.

The Veins.—Of these there are several, approximately parallel, and possessing a strike about north 80 degrees west. One vein outcrops on the roadway between Portions 139 and 182, and extends for a distance of 150

yards at least in a direction a little north of west, with a dip of about 65 or 70 degrees to the north (Fig. 18). The width as measured is from 4 to 8 inches. Very little prospecting has been done, but the few trenches and shallow holes seen in February, 1916, have revealed the existence of a considerable amount of molybdic ochre, and of numerous flakes of molybdenite in the surface stone. The largest hole on the vein was less than 3 feet deep.

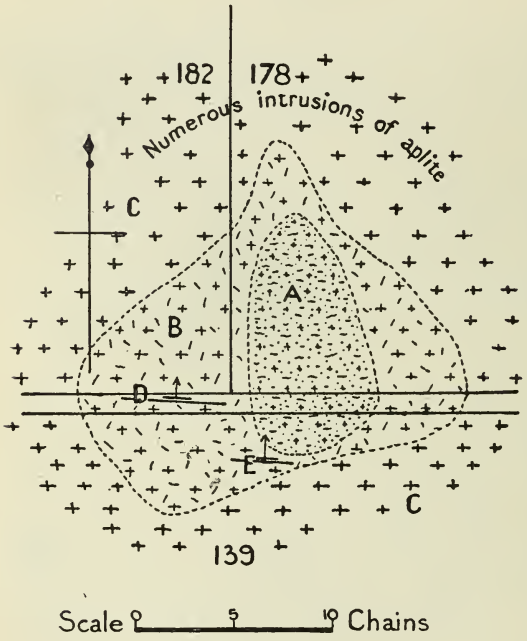


Fig. 18 (*a*).

Parish of Moonbi, County of Inglis.

Betts' Deposits.

A—Coarse sphene. Numerous aplitic veins and knobs intersect the basic or hornblendic granite.

B—Aplite and pegmatitic granite.

C—Pegmatitic granite containing nests of mica and flakes of molybdenite.

D—Quartz vein containing molybdenite 6 to 7 inches wide. Dip 65 degrees to north.

E—Quartz vein with molybdenite flakes 4 to 8 inches wide. Dip 70 to 75 degrees.

In Portion 139, another quartz vein, with well-defined walls, traverses the aplite quite close to its junction with the dark granite. The strike is about north 80 degrees west, the dip is from 70 degrees to 75 degrees towards the north, and the width as seen in the various shallow costeans and holes, varies from 4 to 8 inches. In places the vein has split into two or more smaller portions.

The deepest hole sunk in February, 1916, was about 8 feet long, 4 feet wide, and 5 feet deep. In the vein thus exposed numerous thin flakes of molybdenite could be seen. My colleague, Mr. M. Morrison, has informed me that a shaft 30 feet deep was sunk on this reef prior to his visit in May, 1916.

The Pegmatitic Segregations.—In the south-west corner of Portion 178, a large patch of sandy granite occurs, containing a large patch of pegmatitic material. This pegmatitic material has the appearance of a finely-textured sandy granite, full of small holes or druses, with clusters of interlocking quartz and felspars grains and needles near the small holes, with numerous nests also of soft greenish mica in scales, and with flakes of molybdenite scattered capriciously through the mass as an original constituent. The pegmatitic rock may be traced north-and-south from the contact of the sandy and dark granites for a distance of 150 yards, with a width perhaps of 75 yards (Fig. 18).

This occurrence of pegmatitic material with small scattered flakes of molybdenite as an original constituent, is a common feature in New England, nevertheless it is one which does not appear to be understood by the prospectors of veins, inasmuch as they always appear to expect the scattered molybdenite at the outcrop to be concentrated suddenly, at some slight depth, into payable bodies of definite shape, such as veins, pipes, or shoots. In general it may be noted that, with the exception of certain very rare occurrences, these pegmatitic deposits cannot be expected to present an appearance much different at a depth to that they have at or near the surface, and large as they are they cannot be expected to be mined

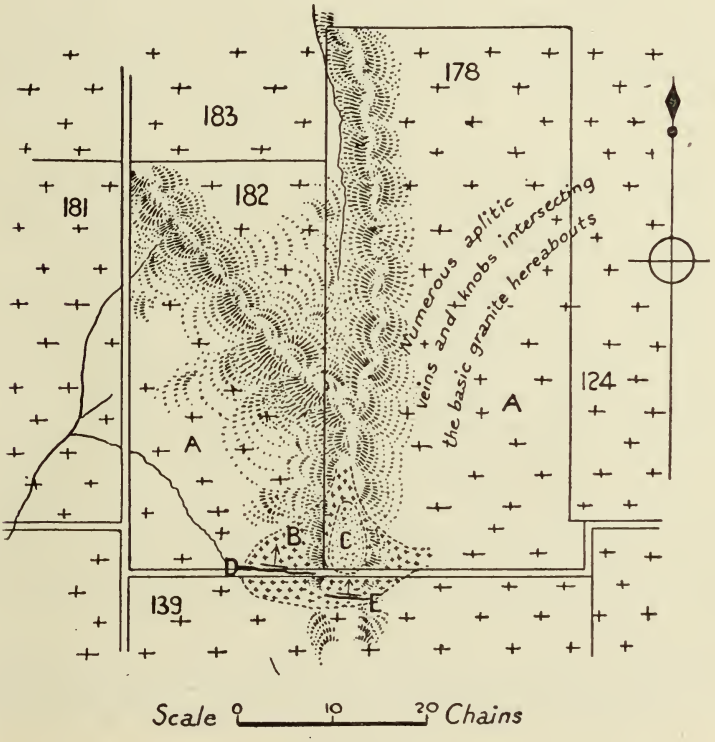


Fig. 18 (*b*).

profitably either as a whole or even selectively at the present price of molybdenite. Certain rare examples, such as that of Booroolong, may be an exception to this general statement.

It is too early to discuss the prospects of the veins themselves, inasmuch as they are small, they would need to be rich to repay the cost of mining and treatment. In a vein averaging 6 inches in width, and with molybdenite at £450 a ton, there should be at least an average of 2 per cent. of this mineral present to secure remunerative results, and this would not provide for any large initial expense, such as might be expected to be expended by a company if purchasing from, or entering into other financial agreement with, the prospectors.

2. Russ and Edward's Claims.—These include several Authorities to Enter and two applications for lease in Parish Perry, County Inglis, within Portions 97 (le Quesne's C.L.), 47 (George Struting's S.L.), and 102 (T. A. Maher's S.L.).

The country is rugged and mountainous, and the deposits lie about 7 miles north of Moonbi. The prospector is Mr. H. F. Russ, according to whose statement the molybdenite was found by him seven or eight years ago while carrying out a contract for clearing suckers in Portion 102. Russ commenced to prospect the area about eighteen months ago, and proved the existence of a couple of true quartz veins carrying molybdenite.

In this locality the dark granite has been intruded by a sandy granite of fine texture. (Pl. XVIII.) The molybdenite deposits have been formed subsequently to the aplite or sandy granite intrusion. A large segregation of pegmatitic aplite occurs in the north-western part of Portion 47, and this contains scattered flakes of molybdenite. Quartz veins containing molybdenite pegmatite occur in Portions 47, 97, and 102.

The Veins.—In portion 102, a quartz vein traverses the dark granite near the intrusive contact of the sandy granite. In places the vein is accompanied at a very short distance by a narrow vein of aplite, traversing the dark granite. The general strike of the vein is north 80 degrees east, and its dip is to the south at a high angle in places, while it is almost vertical in other places. It crosses a knob rising 400 feet above the creek below Maher's homestead, and at the most eastern point yet prospected it is about 4 inches wide, with a steep dip to the south. An open cut has been made here. A few flakes of molybdenite are scattered through the small vein at this point. About 100 yards farther west the vein is 9 inches wide, and is almost vertical. A small vein of aplite accompanies it here at a distance of several feet. A shaft 34 feet deep has been sunk on the vein at this point, and some very fair specimens of quartz containing molybdenite have been won from the shaft. Scheelite also, in irregular lumps as large as hen eggs, was seen in the quartz. About 50 yards to the west a hole has been sunk on the vein to a depth of 12 feet. The vein here is about 6 or 7 inches in width, and about 75 yards farther west the vein appears to die away in "stringers."

A group of small veins carrying molybdenite occurs about 100 yards to the south of the vein mentioned above. These small veins traverse sandy granite of fine texture, and they have the same general strike as the main vein.

In Portion 47 a quartz vein with well-defined walls may be traced for a distance exceeding 440 yards over a rough hill rising 700 or 800 feet above the creek at Maher's homestead. This vein has been proved vertically, by natural processes, for 400 or 500 feet on the western side of the hill.

The vein traverses the dark granite, but it appears to have been due to the action of the sandy granite alongside. The general strike of the vein is north 80 degrees east, and looking along the course of the vein across the creek to the west in Portion 102, the strike of this vein in Portion 47 appears to be continuous with that of the vein on the knob in Portion 102. Nevertheless the vein has not been traced in the valley between the two hillside exposures. A shaft has been sunk to a depth of about 40 feet on the vein about 150 yards from its western end. Here it has walls about

18 or 20 inches apart. The dip is to the north at 70 degrees, and a broken and corroded dyke of dark rock (lamprophyre) occupies the central portion of the vein, but without walls.

The vein is of quartz, but large fragments of corroded and siliceous dyke occur as isolated inclusions. Copper pyrites occurs also in the quartz. Molybdenite occurs somewhat plentifully in large thin flakes. From personal inspection only, I should be inclined to estimate the molybdenite content of the vein in the lower half of the shaft at 1 per cent. approximately.

About 50 yards farther up the hillside a shaft 20 feet deep has been sunk on the vein, which is almost vertical at this spot. The vein is much smaller here and the dyke is larger, and is in the footwall. The molybdenite content appears to be comparable with that in the main shaft. Traced over the rough and rocky hillside to the east, the vein may be seen to decrease gradually in width, and about 300 yards from the eastern side of Portion 47 it is only about 2 inches in width.

M.L. 1 of 20 acres, and M.L. 2 of 10 acres, have been taken up by A. Edwards and Ellen M. Edwards respectively over this vein in Portion 47.

Pegmatitic Segregations.—These occur in the north-western part of Portion 47, near the contact of the sandy and dark granites. The pegmatitic material is fine in texture as in almost all similar occurrences in New South Wales.

It is a large exposure, apparently covering an area of an acre, consisting of an intimate mixture of small interlocking grains and crystals of felspar and quartz, the whole mass being drusy, with small thin flakes of molybdenite scattered quite irregularly throughout the mass, and, so far as exposed at and near the surface by small and shallow prospecting holes, apparently altogether too poor to work as a whole. Future prospecting operations may reveal the existence of rich bunches of ore below the surface, but there is no indication at the surface to justify such a belief.

All of these various veins are very small, and the molybdenite is not at all richly distributed throughout the quartz. In my opinion they are adapted or suitable only for working by small parties of miners without capital, who might be expected to use very simple methods of concentration. The veins are too small, and the molybdenite content is insufficient to justify an outside company being formed to finance the working. This, at least, is the opinion based upon the prospecting done in February, 1916. The amount of molybdenite produced is unknown, but it is quite small.

Nambucca District.

The molybdenite deposits in this district occur within an area of siliceous granite which is relatively small, the ore occurring mainly in small quartz veins within the granite near its intrusive contact with altered sediments. The deposits are spoken of as the Nambucca, Macksville, Warrell Creek, Woy Woy Creek deposits.

The accompanying sketch map of a portion of the field has been prepared by Mr. O. Trickett from measurements and sketches supplied by Mr. J. R. Godfrey, Inspector of Mines.

The earliest official record of molybdenite in this locality appears to have been in 1904, when it was reported* that a "shaft had been sunk 28 feet on a reef 3 feet wide showing good ore. A parcel of 3 cwt. was obtained,

* Annual Report, 1904, p. 55.

and disposed of for £20. It was proposed to sink for 50 feet." From a personal communication from Mr. J. E. Carne, however, it would appear that a Mr. Barker is credited with the discovery of the mineral in 1895 in this locality, though he did not appear to be acquainted with either its name or its properties at the time of discovery. According to Mr. Carne, the molybdenite deposit mentioned in the Annual Report for 1904 occurs in M.L. 16, Parish Warrell, County Raleigh (Fig. 19), and a shaft was sunk thereon to a reported depth of 46 feet.

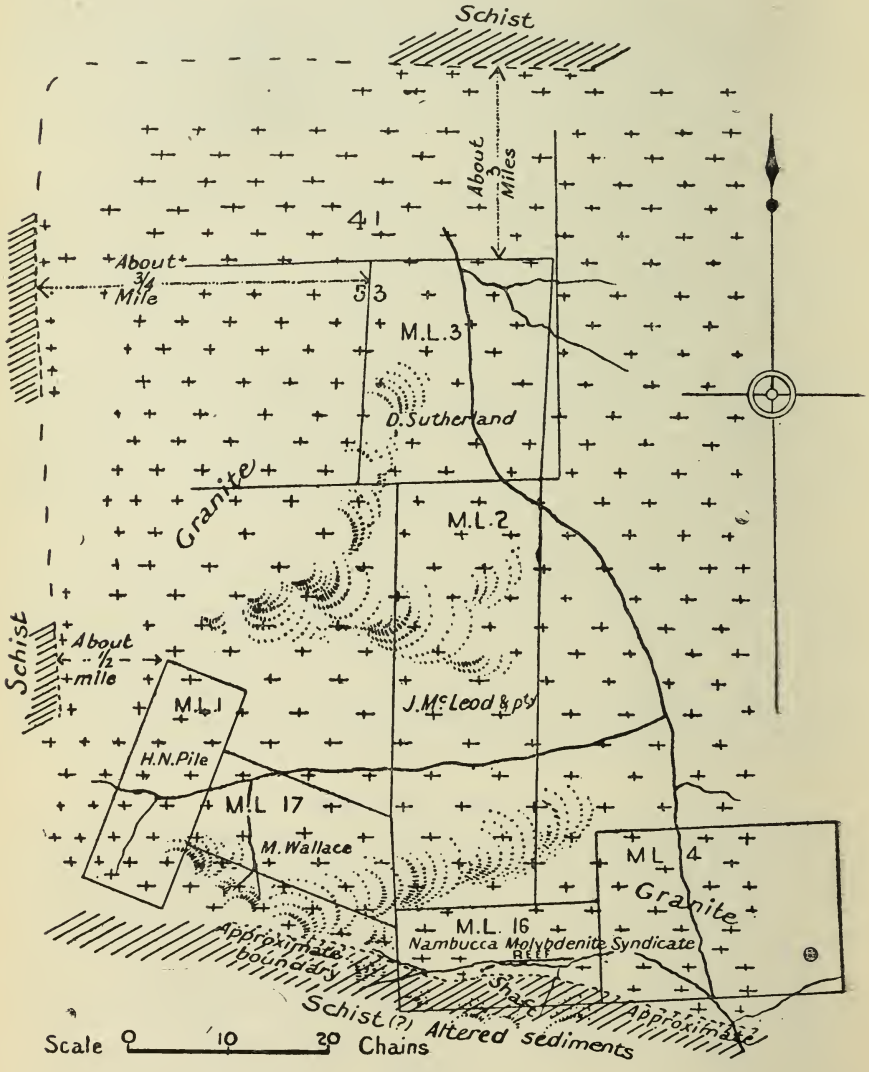
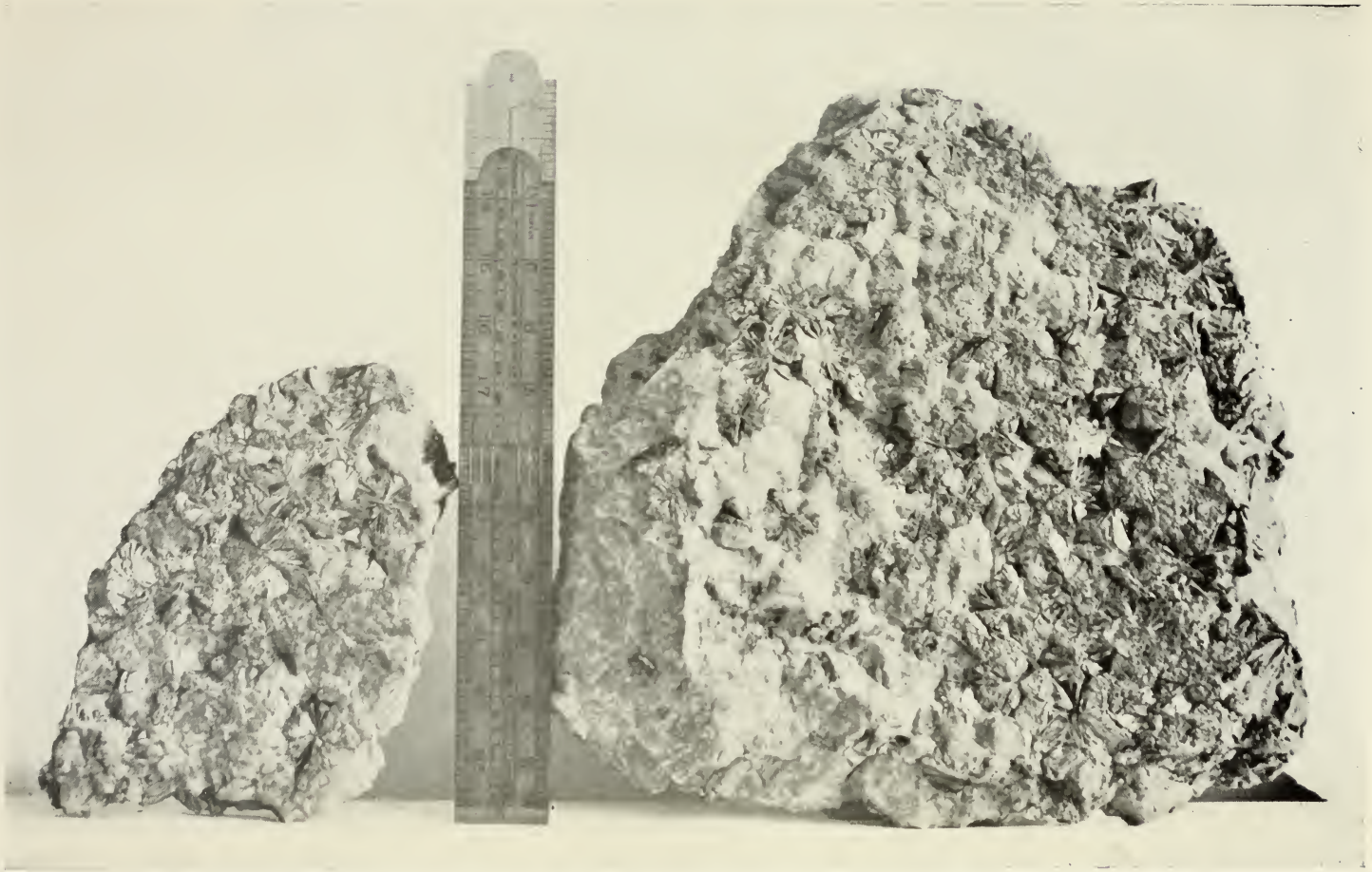


Fig. 19.

Parish of Warrell, County of Raleigh.

Sketch Map of Warrell Creek Deposits—from measurements by J. R. Godfrey.



Quartz veins containing spheroidal and hemispherical crystals of molybdenite. Warrell Creek, Nambucca.

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The locality was examined in March, 1915, by Mr. J. E. Carne, Government Geologist, who has supplied the accompanying notes, together with other notes on individual claims, for this report :—

> "The molybdenite veins occur about 6½ miles southerly by road from Macksville on the Nambucca River, and within 1½ to 2 miles of the North Coast Railway under construction in the northern extension of the Mount Yarrahappini granite, close to its junction with sedimentary rocks."

The accompanying notes on some specimens of country rock from the Warrell Creek deposits have been made by Mr. G. W. Card, Curator of the Mining Museum. The specimens were collected by Mr. J. E. Carne.

Rock specimen 9075.—Granite, light grey in colour, of fine and even texture. It is speckled with biotite, and is not markedly quartzose. Iron pyrites is present.

No. 9076.—A granite similar in appearance and composition to No. 9075. It is a little coarser than 9075, and contains but very little biotite.

Microscopic Characters.

No. 9075.—Much fresh felspar is present, a considerable proportion of which is plagioclase, showing well-marked zoning. Biotite is only subordinate in amount, and shows pleochroic haloes, with zircon. An isolated grain of hornblende was noticed.

No. 9076.—Much of the felspar present is micro-perthitic, and a fair proportion of the felspar also is oligoclase. The felspar is somewhat clouded, and alteration to sericite has commenced. Certain crystals show a clear outer zone. Quartz is under slight optical strain. Biotite is very scarce, and shows more or less bleaching, with some development of sagenite webs. Pleochroic haloes are visible around the zircons.

1. *Kritsch's (L. B.) Claim.*—Notes by Mr. J. E. Carne :—

> "The claim of this name occurs within M.L. 16 of 20 acres. This was the prospecting claim mentioned in 1904. The shaft in 1915 was full of water and consequently not open to inspection, labour conditions having been suspended in March of that year.
>
> "In this lease a series of quartz veins occur, short in length and erratic in distribution, making here and there, at intervals, along a direction varying from N. 80 degrees E. to east and west approximately. As many as three parallel veins may be traced for a few chains in length along the rough channel of the creek.
>
> "Much of the quartz filling is of barren nature, although occasional vughs occur containing molybdenite. The molybdenite content of these veins is 'patchy,' in places, the flakes of the mineral sought are fairly abundant, whereas the intervening areas have a much lower content of molybdenite.
>
> "It is possible that a moderate amount of concentrate might be obtained from the stone lying about the shaft mouth. This would require crushing and screening.
>
> "From this base about 5 cwt. of rich molybdenite concentrate is reported to have been won in 1904."

2. *McLeods' (J. and S.) Claim.*—Notes by Mr. Carne :—

> "J. and S. McLeod's molybdenite claim adjoins that of Sutherland and party (M.L. 3) upstream along Woy Woy Creek, in M.L. 2.

"In this lease some narrow veins of quartz with molybdenite outcrop both in the bed and banks of the creek. In width they vary from mere threads to a maximum of 2½ inches, and their general strike is about north 10 degrees east. These veins, or joint planes, pinch out horizontally within a few feet in places, and they are more or less parallel to each other, although arranged *en echelon* in plan.

"The relatively great width of the barren granite separating the veins, as compared with the widths of the veins themselves, together with the insignificant lengths of the individual veins renders open-excavation methods of mining, such as is the case with some stock-works, impracticable owing to the amount of dead work involved, to say nothing of the extreme hardness of the country rock. Each small vein thus necessitates mining by itself, excepting in such cases where two or three veins may lie within a zone whose width does not exceed that necessitated by ordinary mining operations.

"A shaft was sunk to a depth of 26 feet on an eastern vein which had a width of 1 to 2½ inches, but which did not persist in a horizontal direction. At a depth of 26 feet in the shaft the molybdenite was fairly solid, and, at a lower level, the molybdenite, in places, occupied the whole width of the vein. At these places, as also in the spots where the quartz occupies the greater portion of the veins, the molybdenite occurs as crystals in stellate groups.

"In the granite alongside, parallel veins about one-sixteenth of an inch in width occur in a bank of the creek.

"In these veins the molybdenite is associated with a small percentage of pyrites and chalcopyrite in quartz."

Magnificent specimens of rosettes and crystal clusters of molybdenite in quartz are on exhibit at the Mining Museum through the kindness of Messrs. Hollibone and Parnell. An illustration of this ore is to be seen in Pl. XIX. Fig. 20 also illustrates the association of quartz, molybdenite and country. It is not known whether the specimens shown on Pl. XIX were secured from McLeod's Claim or an adjoining one.

During 1915 it is stated that about 24 tons of ore were raised, estimated to yield about 1 ton molybdenite.

3. *Myra-Lucy Deposit.*—Notes by Mr. J. Carthew, Inspector of Mines.

The deposit is distant about 3 miles in an easterly direction from Warrell Creek, near Butcher's Creek, Parish Warrell, County Raleigh. It was held under Miner's Right on Crown land in 1914. The occurrence was a quartz reef containing molybdenite. The strike of the vein was east and west approximately with a very flat dip to the north. In July, 1914, Mr. Carthew reported (P.B. Papers, 14–3061 Mines), that the work done consisted of trenching and sinking a shaft 6 feet in depth. It was proposed to sink a shaft to a depth of 50 feet "The ore veins are showing in very hard quartz on both sides of the creek. Unlike the deposits at Kingsgate, the mineral is disseminated through the stone. . . ."

4. *Parker's (W. H.) Claim.*—Notes compiled from information supplied from Mr. Parker and from specimens brought in to the Department of Mines at various times by Mr. Parker.

The deposit or deposits are said to occur on the east side of Mount Yarra happini, about 6 miles from Stewart's Point by falling road, and about 3 miles east of McLeod's mine. The specimens shown consisted of large and thick flakes of molybdenite apparently scattered irregularly throughout a

very sandy granite containing small quartz veins. The numerous specimens seen suggest that the molybdenite has been deposited in part in small joints and veins, and that the vapours containing the molybdenite also deposited the mineral, in part, within the granite alongside or near the tiny veins. From an inspection of the specimens this locality appears worthy of being prospected.

Fig. 20.

Sketch section of quartz vein with molybdenite at Warrell Creek in one of the rich portions of the veins.

5. *Sutherland and Party's Claim.*—Notes by Mr. Carne :—

"The deposit nearest to Macksville is that worked by Sutherland and Party on M.L. 3 in the bed and banks of Woy Woy Creek, not far above its junction with Warrell Creek.

"The molybdenite occurs in thin and non-persistent veins or joints in siliceous granite. It is associated with quartz, pyrites, chalcopyrite, galena, and mispickel. The principal vein in this claim has a strike of north 10 degrees west, and, so far as had been proved up to the time of my examination, it had a width of about a quarter of an inch. Other exceedingly narrow veins, or joint planes, occur within an apparent width of 20 feet approximately.

"The molybdenite assemblages, where most pronounced, occur as beautiful crystals having a stellate arrangement.

"Surface prospecting only was in progress in March, 1915."

The following notes have been supplied by Messrs. J. H. Trevarthan and G. S. Ashley.

"H. McLeod's Prospecting Area is on the western slope of Woy Woy Creek, and molybdenite has been found in several places, but a zone of granite with quartz can be traced within the subject area, carrying a fair percentage of molybdenite within a width of 2 or 3 feet. The prospecting holes seen did not exceed 3 feet in depth."

"Ainsworth's Property occurs on the eastern slope, about two miles from H. McLeod's. Molybdenite occurs in the quartz veins and granite."

"North of Macksville, about 10 miles, on the western slopes of Mount England, molybdenite occurs in several places. One or two areas have been taken up, and some prospecting work done therein. On a quartz vein about 2 feet wide, a prospecting hole has been sunk to a depth of 7 feet, and molybdenite can be seen both in the quartz and the surrounding granite."

Monkey Shaft. *See* Kingsgate.
Mount Metallic. *See* Whipstick.
Mount Morgan. *See* Kingsgate.
Mount Tennyson. *See* Yetholme.
Murphy's (Wm.) Claim. *See* Bolivia.
Murphy and Wilson's Claim. *See* Bald Nob.
Murphy and Wilson's Claim. *See* Kingsgate.
Murphy and Young's Claim. *See* Bald Nob.

Myra-Lucy Claim. *See* Nambucca.

Newsome's Block. *See* Glen Eden.

Nymagee.

Molybdenite specks and flakes in a tight quartz in sandy granite. Specimens secured by Mr. D. Jones, a prospector.

Oban.

1. *Lowe's Claim.*—M.L. 73, of 10 acres, at Lode Hill, or Backwater, Parish Coventry, County Clarke, about 30 miles south-south-east of Glen Innes.

The claim under consideration occurs on a plateau about 4,200 feet above sea level, at a point near which the upland falls away suddenly to the Mitchell River, many hundreds of feet below.

Molybdenite occurs within the lease with wolfram in very small quartz veins, and these are grouped in a narrow zone within a very sandy granite near its intrusive contact with a dark hornblendic granite. The granite

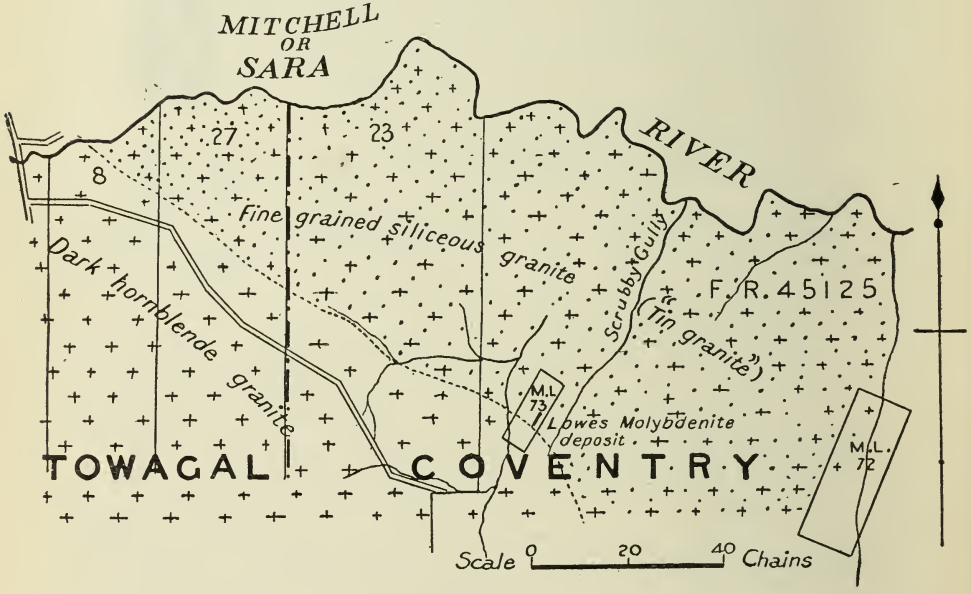

Fig. 21.

Sketch geological map of Lode Hill, in Parishes Towagal and Coventry, County Clarke.

containing the molybdenite veins is the typical tin granite, consisting of an intimate mixture of quartz and felspar, fine in texture, and of a pinkish-grey colour. Here, as in other parts of eastern New South Wales, the tin-granite presents striking contrasts with the associated basic granite. It forms a striking topographic feature, rising abruptly and in rugged manner from the gentle swellings or plain-like appearance of the basic type. Moreover, it is covered with dense scrubby growths of tea-tree (*Leptospermum*), wild daphne (*Brachylome*), whitebeards (*Leucopogon*), geebungs (*Persoonia*), purple pea (*Hovea longifolia*), honeysuckle (Banksia), oak trees (*Casuarina*),

native cherries (*Exocarpus*), bottlebrushes (*Callistemon*), wattles (*Acacia*), and other types, which make surveying a difficult matter. On the other hand, the hornblendic granite, where extensive, may be recognised at a glance by the park-like nature of the country, by the presence of isolated and picturesque tors or clumps of large rounded rocks dotting the plain, by the clumps of open forest composed of New England peppermints (*Eucalyptus nova anglica*), white sally (*E. coriacea*), black sally (*E. stellulata*), white gum (*E. viminalis* and *E. rubida*), and by the large open spaces between the forest clumps, covered thickly with grass and frequented by carolling magpies. The junction of the two types is separated almost as cleanly as with a knife by the plants and the topography, the undulations of the open parkland ending abruptly against the rugged and rocky topography, clad with dense stunted forest and scrubby undergrowth.

The accompanying sketch map (Fig. 21) indicates the approximate junction of the two types between Portion 73 and Mount Mitchell.

The molybdenite veins have a strike approximately N. 35 degrees E., with a dip almost vertical. The strike of the veins is almost at right angles to the general direction of the hornblendic granite and tin granite contact (Fig. 21).

The main vein has been traced for a distance of 60 or 70 yards from the intrusive contact. It is from 4 to 10 inches wide, and it appears to contain very little molybdenite. Almost alongside the granite contact, however, there are several very narrow veins, varying from $\frac{1}{4}$ to 1 inch wide, and these appeared to contain a fair percentage of stout molybdenite flakes. These veins, however, are too small for profitable mining, except by a couple of prospectors, who might mine and concentrate the ore with very simple machinery.

Oberon Deposits.

1. *Duckmaloi River.*—Held under Authority to Enter, of 20 acres, on Portion 133, on private land owned by Johanna Boyle, Parish Norway, County Westmoreland, about 9 miles north-east of Oberon.

The deposit under consideration is known as Dwyer's (D.) Claim. Mr. David Milne, Inspector of Mines, reported as follows in 1915 (P.B. Papers, 15/3717 Mines). "The occurrence consists of granite and garnet rock, containing minute specks of molybdenite and bismuth sulphide. A shaft was sunk on the lode formation some years ago by Messrs. Baker Bros. to a depth of 40 feet, or thereabouts, in the formation. Occasionally a speck of molybdenite can be seen. A crosscut tunnel had been put in also about 40 feet long. . . . . The prospects obtained in the old shaft, and the appearance of the lode formation were poor."

2. *Lowther—Webb and Party's Claim* (also known as Ryan's (M.J.) Claim).—The accompanying notes have been supplied by Mr. E. W. Finch, of Sydney. P.M.L. of 10 acres, on M. J. Ryan's private land. Portion 35, of 83 acres, Parish Lowther, County Westmoreland, about 18 miles from Mount Victoria and 4 miles off main Jenolan Road from Mount Victoria. The deposit is situated on a steep spur of red granite, and it occurs as a series of small quartz veins, one having an average width of 8 inches and underlying about 50 degrees in a southerly direction, the strike being east and west approximately.

Work was commenced here about two years ago by sinking an underlie shaft on the vein, which appears to occur at the junction of sandy granite and an altered rock. The shaft was sunk to a depth of 30 feet on the underlie, and a drive was put out a distance of 20 feet from the bottom of the shaft.

At the end of the drive the vein disappeared, giving place to a "dig," with traces of molybdenite and quartz. This may, of course, be merely a local pinch.

Mr. Finch describes the molybdenite as being contained in the small quartz veins in the form of small but abundant flakes with copper pyrites.

Kirk's (Z.) Claim.—At Duckmaloi. Authority to Enter, of 10 acres, in Portion 164, Parish Norway, County Westmoreland. No information is to hand concerning this deposit beyond the statement of the occurrence of molybdenite flakes.

Information supplied by Mr. Warden Burke.

O'Keeffe's Claim. *See* Glen Elgin.

Old 25. *See* Kingsgate.

Old 26. *See* Kingsgate.

Old 45. *See* Kingsgate.

One and Nine Pipe. *See* Yates' Pipes under Kingsgate.

Orange.

Molybdenite flakes in quartz and granite, in Portion 12, Parish Anson, County Bathurst. Mineral not reserved to the Crown.

Information supplied by Mr. Warden Burke.

Orchard's Claim. *See* Bethungra.

Outcast Mine. *See* Ardlethan.

Packer's Swamp. *See* Tantawanglo.

Pambula.

"A band of this conglomerate runs along the east side of the intrusive porphyry for more than two miles in the direction of the prevalent strike of the Coast and Black Ranges, which is towards south-south-east, and is distinguished by veins of quartz with abundance of *molybdenite* on the road to Eden."*

Parker's (W. H.) Claim. *See* Nambucca.

Petrie's (John) Claim. *See* Rocky River.

Petrie's (W. F.) Claim. *See* Rocky River.

Pheasant Creek. *See* Glen Elgin.

Pheasant's Nest Mine. *See* Mount Metallic, under Whipstick.

Piesse and Baker's Lease. *See* Ardlethan.

Potter's Blow. *See* Sachs of Kingsgate, under Kingsgate.

Pye's Creek. *See* Bolivia.

Queensgate Mine. *See* Black Range.

Quinn's Find. *See* Kingsgate.

Reake's Claim. *See* Gemalla, under Yetholme.

Reef Blow. *See* Yates' Pipes under Kingsgate.

Reef Blow. *See* Sachs of Kingsgate.

Reid and Weir's Claim. *See* Boundary Creek, under Rocky River.

Road Pipe (Sachs of Kingsgate). *See* Kingsgate.

Road Pipe (Yates). *See* Kingsgate.

Roberts and Heiss. *See* Rocky River.

Robertson (E. H.). *See* Booroolong.

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* W. B. Clarke. Southern Gold-fields, p. 190.

The Rocky River or Wunglebung Deposits.

The molybdenite deposits of the Rocky River or Wunglebung, are instructive and interesting in that, although they fall under the head of "pipes in granite," nevertheless, as a group, they exhibit certain features peculiar to themselves.

The locality lies about 26 miles south-east of Tenterfield, in a very deep and wild valley. The road leading from Tenterfield starts at a height above sea-level of 2,850 feet, and rises to a height of 3,100 feet above the same level in a distance of 11 miles. It has an indifferent surface and is of the switchback variety. Thence a descent of 2,000 feet is made to Demon Creek, the road on this section needing more cuttings to avoid the steep sidelings. From Billyrimba to Wunglebung, on the Rocky River, a distance of 6 miles, the road is almost impassable in wet weather owing to the greasy nature of the yellow clay of the cuttings made in the dark felspar porphyry. Freight per ton to the railway at Tenterfield is said to be £4, or 3s. a mile.

Wolfram, bismuth, and molybdenite, are the minerals mined, wolfram being found in greater quantities than either bismuth or molybdenite. These minerals occur in pipes of quartz or altered granite with pegmatite within coarse sandy and granular granite near its intrusive contact with two lava porphyries, one a dark felspar type, the other a light grey quartz-felspar type.

The granite containing the pipes presents differences from those containing the important molybdenite and bismuth pipes of Whipstick, Kingsgate, Bolivia, and Deepwater. The latter, in common with the Rocky River types, are coarse, granular, and sandy, but they cut the associated claystones, slates, or porphyries, with sharp lines, there being little trace of variable or nondescript rock development at their margins. The granite of the Rocky River, in common with that at Rummery's Claim (Fig. 9) intrudes the associated rocks in places only with clearly defined lines, while in other places it possesses a mantle of aplite, pegmatite, greisen, or siliceous material (Pl. XXI).

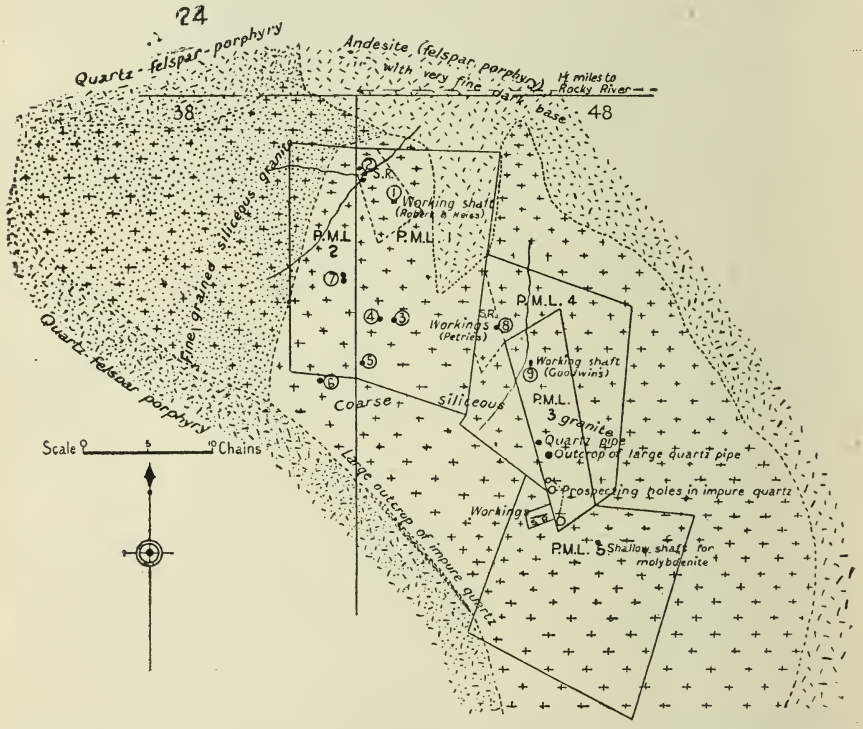
The coarse granite, also, of the main intrusion is more siliceous than the granites of the Bolivia, Deepwater, Kingsgate, and Whipstick, pipes, and indeed of other places in New South Wales containing molybdenite and bismuth pipes without wolfram and tin. It resembles the great siliceous or sandy granite of the Mole Tableland rather than the Kingsgate and other molybdenite granites.

All of the granites of the district appear to have intruded Permo-Carboniferous sediments. The very sandy granites of Poverty Point containing gold pipes a few miles to the north form a high plateau east of Demon Creek, a tributary of the Rocky River. This high and rugged upland is flanked by "dark granite" types, containing abundant hornblende and sphene, and which the Poverty Point granite appears to have intruded. The floor of Demon Creek Valley, as also that of the Rocky River at Billyrimba and Wunglebung, consists of a felspar porphyry, whose base is very dark and almost flinty in texture. Near the leases worked for wolfram, molybdenite, and bismuth, the porphyry has been intruded by a granite mass, whose summit has been exposed by the denudation of the overlying and surrounding porphyry. The granite has only been exposed as to its summit (Plate XX). On the western side of the granite a quartz-felspar porphyry forms a rugged boundary.

The contrast between the granite and the dark porphyry is illustrated strikingly by the characteristic vegetation of the two formations. The porphyry, which decomposes into an extremely greasy clay, supports abundant growths of silver-leaved ironbark (*Eucalyptus melanophloia*), grey box (*E. hemiphloia*), blue-gum (*E. saligna*), red stringybark (*E. eugenioides*), red mahogany (*E. resinifera*), river red-gum (*E. rostrata*), red-gum (*E. tereticornis*), tallow-wood (*E. microcorys*), ironbark (*E. crebra*), and other forest trees. Little or no undergrowth was seen on this rock type.

The peculiar bluish-green colour of the foliage of the abundant silver-leaved ironbark was observed to end abruptly against the duller green of the sandy granite vegetation, the latter consisting of bloodwood (*Eucalyptus*

PLATE XX.



Sketch geological map of Wunglebung Deposits. Rocky River, Parish of Wunglebung, County of Clive.

corymbosa), brittle red-gum (*E. dealbata*), red stringybark (*E. eugenioides*), tea-tree (*Leptospermum scoparium*) in thickets, clumps, and massed growths, native hickories and wattles (*Acacia longifolia*, *A. penninervis*, *A. glaucescens* (?), *A. nereifolia*) and some beautiful shrubs with yellow pea blooms.

To the immediate north the conical tops of several diorite intrusions are exposed in the bases of the deep and steep gorges, which make transport so difficult in this country. These cones are connected with each other probably at a slight depth. They appear to have no connection with the molybdenite and associated minerals. Several miles to the south, however, in the narrow bottom of a wild and rugged ravine, called Boundary Creek, three

knobs, dome-shaped, of sandy or siliceous granite form isolated outcrops. One knob is 200 feet in height, the others do not exceed 50 feet in height above the base of Boundary Creek. All have intruded the quartz-felspar-porphyry which forms so much of the country hence to Glen Innes, Deepwater, Bolivia, and Tenterfield. All are doubtless connected with one another, and with the Wunglebung outcrop at a depth.

These sandy granites, particularly that exposed in M.Ls. 1 and 2, Parish Goolamanger, in Boundary Creek, are associated with wolfram and molybdenite deposits.

The distribution of the pipes and other deposits is shown on Pl. XXI, and in Fig. 22. The deposits occur within the sandy granite near its intrusive contact with the porphyry.

An examination of the exposed granite humps suggest that here, in great measure, we have the original slope and surface of the granite summits, and that much of the flinty and siliceous débris of the surface, as for example, that seen in Goodwin's lease, is part of the original mantle of the granite. Numerous pipes, unprospected as yet, dot this granite roof and suggest the tendency of the granite vapours to escape into the surrounding cooler rock masses, especially in the upper portions. The Whipstick granite is also a magnificent example of this action in the south-eastern portion of the State.

History of Field.—According to Mr. Frank Roberts, it is believed that a hole 3 feet deep was sunk for gold about forty years ago on a large outcrop of quartz near Roberts and Heiss' shaft, and known as "The Quartz Blow." Nothing of importance was found at the time, nevertheless had the prospectors continued the sinking for a few feet, they could not have missed the molybdenite flakes which were scattered abundantly through the quartz. Mr. W. Smith, a selector, about the year 1912, found wolfram in what is now known as Goodwin's Lease. This outcrop was then examined by Messrs. Scott and Lock, together with Mr. W. H. Yates, of Kingsgate. Mr. Goodwin, of Kingsgate, at a later date, proved it to be a quartz pipe containing wolfram and molybdenite. In September, 1913, Mr. Frank Roberts prospected the surrounding areas, and in company with Mr. Fred. Heiss, secured P.M.Ls. 1 and 2.

A rich pipe was prospected by Roberts and Heiss, and a small plant for treating the ore locally was erected to offset the enormous transport charges to the railway (£4 a ton). Owing to the complex nature of the ore, this plant did not meet with success, and various parcels were sent to the Sydney Export Company for treatment.

A. *Boundary Creek.*—The deposits of this locality were prospected about fifteen years ago by Mr. F. Heiss, who showed molybdenite specimens from there to a local mining expert, by whom the mineral was said to be plumbago and worthless. The prospecting operations were abandoned temporarily. Leases were taken up about 1914 on opposite sides of the creek, covering the small exposure of sandy granite in the base of the ravine (Fig. 22). The lessees were Mr. Percy Reid and Mr. Adams. The leases are 6 miles by very rough bridle track from Wunglebung.

1. *Adams' Claim.*—P.M.L. 1, of 10 acres, Parish Goolamanger, County Clive. The granite is exposed as a knob or dome about 60 to 80 feet above the creek bed. This dome appears to be the original surface of the granite excrescence, and it is covered, in part, with the intruded porphyry. Small patches of rock containing wolfram, molybdenite, and hornblende, or similar material, have been found on the knob alongside the creek. Very little prospecting work has been done on the lease.

2. *Reid and Weir's Claim.*—M.L. 1, of 20 acres, Parish Goolamanger, County Clive. The country is very rugged and steep, rising precipitously just beyond the creek. The granite (Figs. 22 and 23) outcrops only in the base of the ravine, and dips at a flat angle to the north-west, north, and east, under the quartz-porphyry, the greatest height above the creek bed of the exposure

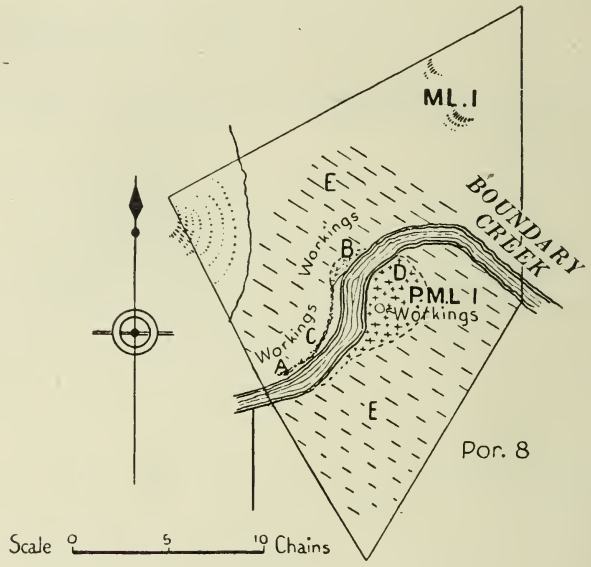


Fig. 22.

Parish of Goolamanger, County of Clive.

A—Outcrop quartz (pipe?).
B—Granite and fine pegmatite containing molybdenite and wolfram.
C—Pegmatite mantle, about 4 feet thick.
D—Coarse siliceous granite.
E—Filtered sediments and quartz-felspar-porphyry.

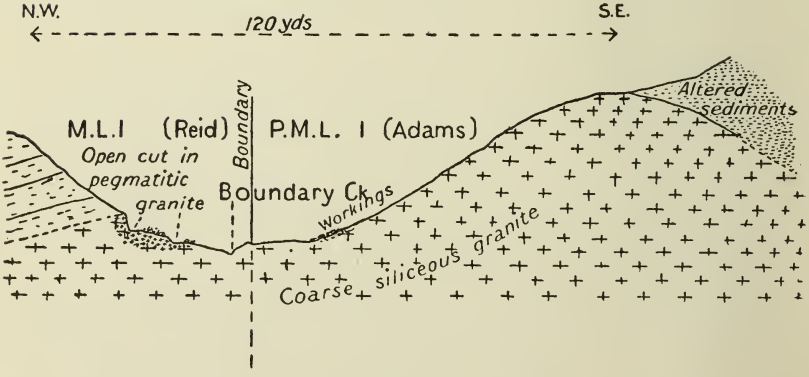


Fig. 23.

Sketch section across Boundary Creek showing the general relations of sediments to the quartz porphyry and the intrusive granite.

being only a few feet (Fig. 23). The granite is exposed for 225 to 250 yards in the left bank of the creek within M.L. 1, and at the widest point across both M.L. 1 and P.M.L. 1, it does not exceed 150 yards.

On its northern or north-western portion for a length of 200 yards this granite has a mantle of coarse pegmatite, varying from 2 to 5 feet in thickness. Above this lies the porphyry or altered sediments, while below the mantle the coarse sandy and granular nature of the granite is apparent. This mantle gives place in the extreme eastern portion of the granite outcrop to a peculiar form of granite, lacking the coarse pegmatitic nature of the remarkable mantle further west. This eastern mass of silicified granite has a maximum length of 70 feet, forming a blunt wedge from 30 to 40 feet in width, and of unknown depth. The mass dips under the overlying porphyry at a low angle. From a heap of 100 tons moved from this mass of silicified granite, Mr. Hughie Weir states that 1 ton of wolfram has been handpicked, while a considerable amount of molybdenite and wolfram remains in the rejected material.

The pegmatite mantle (Fig. 24) is studded irregularly with molybdenite and wolfram, but of very low grade.

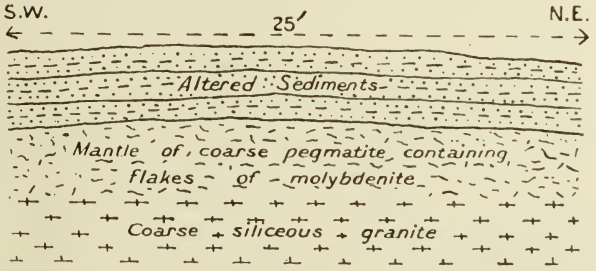


Fig. 24 (*a*).

(*a*) Sketch section in Boundary Creek, Reid's Claim, M.L. 1, Parish of Goolamanger, County of Clive. The granite dips to the north-west at a very gentle angle.

At a distance of 40 yards downstream from the westernmost point of the lease (M.L. 1), a mass of quartz and coarse pegmatite outcropped in the rocky stream bed. A hole was sunk in this outcrop about 3 or 4 feet deep, and about 8 feet across. The hole is now filled in great measure by stream débris, but according to Messrs. Reid, Roberts, and Weir, about 4 tons of stone were raised hence, from which 75 lb. of wolfram, and 1 ton of 4 per cent. molybdenite ore were handpicked, while 2 or 3 tons of stone lie on the surface apparently containing about 2 per cent. molybdenite. This quartz outcrop may represent a "pipe" in the granite, or again it may be only a prolongation of the pegmatitic mantle alongside.

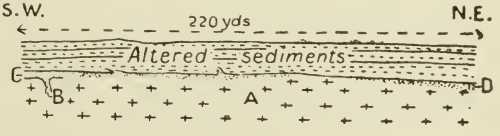


Fig. 24 (*b*).

Sketch section in Reid's Claim, M.L. 1, Parish of Goolamanger, County of Clive, showing mantle of coarse and fine pegmatite exposed in workings in creek bank.

A—Siliceous granite.

B—Probable pipe of quartz.

C—Thin mantle of coarse pegmatite containing molybdenite and wolfram.

D—Fine pegmatitic granite containing molybdenite and wolfram.

It appears advisable to prospect this quartz and pegmatite further, and it also appears advisable to take samples across the large wolfram exposure at the eastern end of the granite, and to form some idea of the depth to which this ore body persists. If this body of granite really yields from 1 to 2 per cent. of wolfram it would be a valuable deposit.

B. *Wunglebung Deposits.*—1. Goodwin's Claim, P.M.L. 3.—This lease is worked by Goodwin and Party, and covers very steep granite country, the granite being coarse and sandy. Several pipes outcrop on the hillside, but the deposit worked at present is indicated on the map (Pl. XX), as No. 9, being a pipe of white quartz outcropping alongside a creek in precipitous country. The greater measurements of the pipe in cross-section are about 10 by 8 feet. In September, 1915, it had been worked to a depth of 30 feet along the dip, the latter being about 60 degrees. At this depth the pipe appeared to split. In February, 1916, the shaft was about 40 feet deep, and the pipe branches were seen to have united below what perhaps may be called a granite horse.

The general arrangement of the minerals in the upper portion of the pipe was somewhat as shown in Fig. 25.

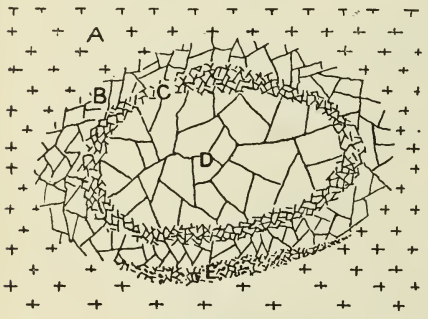


Fig. 25.

Idealised section across Goodwin's pipe, as seen in 1915.

A—Coarse siliceous granite.
B—Light grey quartz containing wolfram.
C—Milky and transparent quartz with abundant flakes of molybdenite.
D—Compact, white quartz, with very little wolfram, bismuth, or molybdenite.
E—Compact grey quartz, non-cavernous, with a considerable amount of bismuth.

In the typical cross-section the "footwall" portion varied from 1 to 4 inches in thickness, and was of compact, non-cavernous, grey quartz. In the "gutter" of the "footwall," according to Mr. Goodwin, the bismuth occurs. The wolfram and molybdenite contents appeared to be arranged in the outer portion of the pipe, the wolfram being developed, typically, in an outer, and the molybdenite in an inner, ring, the quartz enclosing them being compact and non-cavernous. The central portion of the pipe contained a large proportion of white quartz with a low wolfram and molybdenite content.

Higher up the hillside a couple or more of very fine quartz outcrops are to be seen (Pl. XX). These appear to represent a large pipe and its branches. These have not been prospected as yet.

Production.—According to Mr. H. A. Goodwin, the production till the end of 1915 was 3 tons containing 65 to 67 per cent. tungstic acid, 15 cwt. containing 93 per cent. molybdenite, 1 cwt. bismuth.

A heap about 7 tons in weight was lying at the mouth of the pipe.

This appeared to contain about 1 per cent. molybdenite and a high content of tungstic acid, perhaps exceeding 8 per cent.

2. Petrie's (John) Claim.—Now known as the Rocky River Wolfram and Molybdenite Syndicate, managed by Mr. G. F. Litchfield, P.M.L. 4, of 12 acres, Parish Wunglebung, County Clive. Adjoins Goodwin's Claim (Pl. XX). The country is of coarse sandy granite. On the map the deposit worked is indicated as No. 8. At the surface the deposit appeared to be a

quartz vein of peculiar form. By following the quartz for a length on the underlie of 40 feet and a vertical depth of 22 feet it appears to have formed a small pipe about 3 feet in diameter. The quartz in the face, as seen in February, 1916, appeared to form the centre of the pipe, with molybdenite forming an outer zone. Wolfram occurred near the footwall.

A small cracker and rolls driven by a whim horse is employed to treat the ore. The circle walked by the horse is about 22 feet in diameter, and the diameter of the drum is perhaps 3 feet. The plant is valued at £50.

Production.—1914. Not known.

1915. 25 tons of ore, estimated to produce 4 cwt. molybdenite, valued at £76. Wolfram also occurs with the molybdenite.

3. Petrie's (W. F.) Claim.—P.M.L. 5, about 19 acres, adjoining Goodwin's Claim (Pl. XX) in rough granite country. Small prospecting holes have been sunk here upon quartz and other siliceous outcrops. Very little work has been done, and nothing was being done during my visits in 1915 and 1916. A large mass of impure quartz and granite occurs at the junction of the granite and porphyry alongside this lease as shown on Plate XX. The area appears to be worthy of prospecting.

4. Roberts and Heiss' Claim.—P.M.L. 1, about 18 acres, and P.M.L. 2, about 9 acres, Parish Wunglebung, County Clive (Pl. XX).

The leases occur in very rough country composed of siliceous and coarse granular granite intrusive into dark and light-coloured porphyries. The main workings are connected with the Rocky River at Wunglebung by a steep track about $1\frac{1}{4}$ miles long.

A considerable number of deposits are known to exist on the two leases, as may be seen by a glance at the accompanying map (Pl. XX). The deposit marked 3 on the map is a large wolfram pipe outcropping as a mass of tight granular quartz with encouraging prospects for wolfram. Deposit 4 is suggestive of a typical white outcrop of quartz at Kingsgate, and large flakes of molybdenite occur in abundance in the outcrop or quite near the surface. Deposit 5 is known as the Tin Pipe, and outcrops as a mass of quartz containing same tinstone, molybdenite, bismuth, and wolfram. Deposit No. 7 possesses a large outcrop of grey quartz with a fair wolfram content. It also possesses an outcrop of quartz and granite containing native bismuth and wolfram. Deposit No. 2 includes what appears to be a bismuth pipe, and a pipe outcrop containing much quartz and with a fair content of wolfram, molybdenite, and bismuth.

The deposit marked 1 is a quartz and granite pipe containing wolfram, molybdenite, and bismuth. The size of the pipe in cross-section appears to be about 10 feet x 6 feet. From the surface the deposit was followed in a direction about north 40° east, at an angle of 50 or 60 degrees to the horizontal. At a depth of 40 feet, as measured along the underlie, the pipe was found to have a direction of north 40° west, with a dip of 50 degrees. A vertical shaft 35 feet deep was sunk to facilitate mining operations. Near the bottom of the shaft the pipe was followed in a direction almost north 40° east.

Excrescences, short processes, or vertical arms of quartz occur along the back of the pipe, and these are arranged in a manner such as to suggest the influence of a joint, or joints, in the formation of the main pipe. The prospectors, Messrs. Roberts and Heiss, appear to have been aware beforehand of the great bend in the pipe from north-east to north-west by

observing the changes in the arrangement of these vertical quartz processes or excrescences. Fig. 26 illustrates the arrangement of the minerals in that portion of the pipe exposed in the face, or bottom, in September, 1915. Wolfram and bismuth occurred in a light grey and compact quartz at the lowest portion of the deposit or "footwall," while above this, about 2 feet above the bottom, an assemblage of bismuth and molybdenite was seen with numerous long crystals of decomposed beryls. Above this was a rock material which appeared to represent granite altered to grey granular and compact quartz, and containing some wolfram and bismuth. A very compact, granular quartz, grey in colour, and rich in wolfram was lying upon the altered granite, while above the wolfram a seam of molybdenite ore occurred, varying in thickness from 1 to 12 inches. The Hanging Wall, so-called, was composed of altered granite containing molybdenite, but no bismuth.

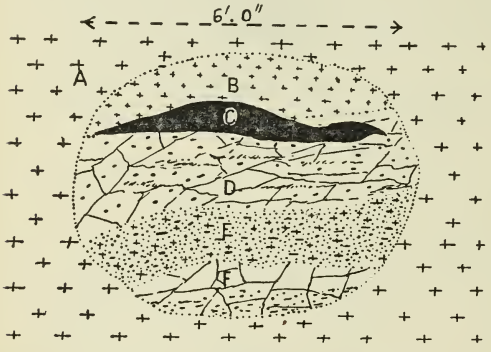


Fig. 26.

Sketch section across face of Roberts and Heiss' pipe in September, 1915.

A—Coarse siliceous granite.
B—Granite altered by silicification.
C—Vein rich in molybdenite from 2 to 10 inches thick.
D—Dense grey granular quartz very rich in wolfram.
E—Granite altered to grey quartz, with wolfram and bismuth.
F—Bismuth, wolfram, molybdenite, and beryls in light grey compact quartz. (Richest bismuth in "gutter.")

In February, 1916, the pipe at the face was steep, while rich molybdenite, in seams, was visible in the roof. Wolfram was also observed in fair quantity in the face.

Production.—According to Messrs. Roberts and Heiss the production up till December, 1915, was :—

Wolfram.—2 tons 5 cwt. (70 per cent. tungstic acid).

Molybdenite.—2 tons 12 cwt. (90 per cent. molybdenite).

Bismuth Sulphide.—5 cwt.

A large heap of ore, about 90 tons in weight, is lying at the shaft. This is very rich ore, possibly containing as much as 10 per cent. of wolfram, bismuth, and molybdenite combined.

A magnificent specimen of this complex ore is on exhibition at the Mining Museum, Miller's Point, Sydney.

5. Vaughan's Claim.—P.M.L., 10 acres, adjoining Roberts and Heiss' claim.

The country is of granite, and contains certain siliceous outcrops, one of which is indicated on the accompanying map as No. 6, or the Mica Pipe. It is apparently a mass of granite which has been altered in great measure to soft secondary mica and impure quartz, the felspars especially being altered. It contains the usual association of minerals characteristic of the locality. Mr. Vaughan has sunk a certain distance upon the pipe, but no returns of ore won have been reported as yet.

6. Other Prospecting Areas.—Many other Authorities to Enter have been applied for within Portions 24, 38, and 48, Parish of Wunglebung, and several Authorities have been held also on Portions 6 and 8, Parish Goolamanger. From all of these molybdenite has been reported.

Future of Wunglebung or Rocky River Locality.—The locality as a whole is well worth careful prospecting. The leases already in force are deserving of careful and systematic work, particularly P.M.Ls. 1, 2, 3, and 4. The pipe at present being worked by Roberts and Heiss has only been worked to a depth along the underlie of 60 feet or thereabouts. Nevertheless about 5 tons of molybdenite, wolfram, and bismuth have been sent away, and apparently about 8 or 10 tons more of these minerals lie at the surface in the form of a rich complex ore. This indicates a very rich yield from a shaft 60 feet deep, and from 6 to 10 feet diameter.

A good road to Tenterfield would help the district considerably.

Ruming's Claim. *See* Kingsgate.

Rummery's Claim. *See* Deepwater.

Russ and Edward's Claim. *See* Moonbi.

Ryan's (M. J.) Claim. *See* Lowther under Oberon.

Rye Creek. *See* Burrowa.

Sachs' Folly. *See* Kingsgate.

Sachs of Kingsgate. *See* Kingsgate.

Sachs' Old 45. *See* Kingsgate.

Schaefer's (H.) Claim. *See* Booroolong.

Scott's Reef. *See* Black Range under Bega.

Serpentine River. *See* Guy Fawkes.

Skeleton Creek.

Twelve miles east of Glen Innes. Molybdenite flakes in granite. Information supplied by Messrs. Jamieson and Griffith, of Sydney.

Snape's (P.) Authority. *See* Booroolong.

Slade's Blocks. *See* Yetholme and Gemalla.

Spencer's (A. S.) Claims. *See* Laura Creek.

Splitter's Swamp. *See* Bolivia.

Sproull's Authorities. *See* Elsmore under Tingha.

Staine's Lease. *See* Wilson's Downfall.

Stalling's Lease. *See* Wilson's Downfall.

Stanley's (W.) Claim. *See* Booroolong.

Stewart's Point. *See* Nambucca.

Sugar Loaf Mountain. *See* Wilson's Downfall.

Summerell's Claim. *See* Tantawanglo.

Sunrise Mine. *See* Bolivia under Cooper's Claims.

Sutherland and Party's Claim. *See* Nambucca.

Sydney Tin Mine. *See* Middle Creek under Tingha.

The Tantawanglo Deposits.

Topography.—The Monaro plateau from Cooma to Bombala and Cathcart is high and bleak and is covered in the main with stunted growths of eucalypts. At a distance from the sea of 30 to 40 miles this wind-swept upland breaks away to the coastal lowlands by means of wild and tumultuous profiles. The main lines of descent to the coastal area are at the

Brown Mountain, the Tantawanglo, and the Big Jack, about 3,200, 2,600, and 2,200 feet respectively. From this great, but broken, eastern escarpment of the Monaro plateau long high spurs extend eastward. These east and west spurs, of which the Wyndham and Wolumla Mountains are examples, form watersheds between such rivers as the Bega and the Towamba. These spurs, in turn, mark residuals of the Monaro plateau which once extended with gradually-falling surface to the coastal ranges at Bega, Eden, Wolumla, and Tathra. The Bega and Towamba waters have excavated their own great valleys, and are now busily occupied in still gnawing their way headward into the great Monaro Plateau. At one time it was thought by the Writer* that the great eastern escarpment of the plateau had been due to faulting or warping of the coastal area, but upon personal examination of the area it was evident that the topography was due to stream action on rocks of variable strength.

One of the main points of descent of the range is the Tantawanglo Mountain, and the molybdenite deposits known as the Tantawanglo occur, for the most part, on the upper portion of the great plateau escarpment at this point.

From the plateau towns, such as Bombala, Cathcart, and Cooma, the mountain is approached by good undulating roads, but the approach from Bega and Eden is by long steep mountainous roads, which, however, have fair surfaces. From Bombala, Cathcart, and Bega the Tantawanglo summit is distant about 18, 8, and 33 miles respectively.

The whole of the great Tantawanglo Mountain is composed of siliceous granite, but the basalt of Monaro comes within a very short distance of the eastern escarpment of the mountain at the summit of the road. Magnificent forests of gigantic eucalypts abound in the ravines and on the slopes of the mountain.

The siliceous granite of which the mountain is composed is dotted here and there with very large segregations, or intrusions, of aplite and pegmatitic granite in which scattered molybdenite flakes occur as an original constituent. These deposits are very large, one being several hundreds of yards in length and several hundreds of feet in width at the surface. Nevertheless, there is no evidence as yet of any natural concentration into commercial deposits within these great outcrops. No pipes, nor veins, containing molybdenite have been found, and the deposits are altogether too poor to be worked as a whole. There thus appears to be little hope of mining these deposits at a profit.

According to Mr. P. J. Knox, a resident on the summit of the mountain, the place was prospected for molybdenite about three years ago by Mr. W. J. Tarlington and another. They found specks of this mineral in M.L. 2. After this discovery Messrs. P. J. and T. Knox found specks of the same mineral on M.L. 4. M.L. 2 was then applied for. A prospector named Mr. Jessop meanwhile had found molybdenite on the area now covered by M.L. 6. Another prospector named Mr. Hammond found the mineral within M.L. 3. T. Knox then took up M.Ls. 5 and 9. M.L. 12 was taken up as a machinery site, and M.L. 10 was taken up at a date slightly later by Taylor and Adams.

Another deposit found in the vicinity of M.L. 6 was A. L. Fulton's in M.L. 8.

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* E. C. Andrews. The Geographical Unity of Eastern Australia. Procs. Roy. Soc. N. S. Wales, vol. XLIV, 1910, pp. 420-480.

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PHOTO-LITHOGRAPHED BY W.A. GULLICK, GOVT. PRINTER, N.S.W.

All these occur in Parish Bredbendoura, County Auckland.

Other deposits found in the neighbourhood were Summerell's on Portion 95, Parish Creewah, County Wellesley, A. J. Fulton's M.L. 1, in Parish Yuglamah, County Auckland, and R. H. Clarke's claims on Packer's Swamp, Parish Thoko, County Wellesley.

1. *Clarke's Claim.*—According to Mr. R. H. Clarke the deposit occurs about half a mile from the head of Packer's Swamp, Parish Thoko, County Wellesley, about 9 miles from Holt's Flat. The molybdenite occurs as scattered flakes in quartz and aplitic or pegmatitic granite, and according to the same authority the mineral has been found as at least six distinct outcrops over a distance of about a quarter of a mile. Some of the specimens forwarded to the Department of Mines by Mr. Clarke possess a fair percentage of molybdenite, but the average stone appears to be low in grade.

2. *Fisher's (E.) Claim.*—This has been covered by M.L. 7 of 10 acres, Parish Bredbendoura, County Auckland. It is an area of siliceous granite in which infrequent flakes of molybdenite have been found. Very little prospecting has been done on this block.

3. *Fulton's (A. G.) Claims.*—These include M.L. 8 of 10 acres, in Parish Bredbendoura, County Auckland, and M.L. 1 of about 10 acres, Parish Yuglamah, County Auckland. The former of these is a mass of aplitic or pegmatitic granite surrounded by siliceous granite of more normal type. The outcrop contains scattered flakes of molybdenite. Prospecting operations have been confined to the sinking of a shallow shaft and a little surface work. Nothing of commercial value has been reported.

The second lease is in siliceous granite also, within which an outcrop of quartz and felspar occurs, containing flakes of molybdenite. A shaft has been sunk to a depth of about 20 or 25 feet, and some fair specimens of molybdenite and molybdic ochre have been obtained. Nothing of commercial importance appears to have been won as yet. [General information supplied by Mr. A. G. Fulton.]

4. *Hammond's Claim.*—M.L. 3 of 20 acres, Parish Bredbendoura, County Auckland. This lease is in siliceous granite, within which a large outcrop of aplitic or pegmatitic granite has been found, containing flakes of molybdenite. [Information supplied by Mr. P. J. Knox.]

5. *Jessop's Claim.*—M.L. 6 of 10 acres, Parish Bredbendoura, County Auckland. The country is of siliceous granite, and in the southern portion of the lease an outcrop of aplitic or pegmatitic granite occurs, about 200 feet in diameter. As in all the Tantawanglo deposits, this aplitic type is of fine texture. Molybdenite occurs throughout the outcrop in small scattered flakes, without concentration at any particular point. Prospecting operations have been confined to surface napping and to the sinking of several holes about 12 feet in depth.

6. *Knox's Claims.*—These consist of M.Ls. 2, 4, 5, and 9, which were taken up by Messrs. T. and P. J. Knox after prospecting.

(*a*) M.L. 2, 10 acres, Parish Bredbendoura, County Auckland. The lease is connected by fair bush track with the main road near the summit of the Tantawanglo. The country rock is a siliceous granite, which appears to be traversed by a mass of aplitic and pegmatitic granite about 400 yards in length and 150 yards in width. This granite is fine in texture, and it contains numerous small holes and small patches of quartz.

Small flakes of molybdenite are scattered with a sort of regular irregularity throughout the aplite, but no concentration into pipes, veins, or large patches or "bungs," has been proved. Nowhere has any one mass of, say, 10 tons of stone *in situ* been found which contains more than one tenth of 1 per cent. of molybdenite. Prospecting has been confined to the breaking of surface stone, and to the sinking of shallow holes in the great outcrop.

(*b*) M.L. 4, 20 acres, Parish Bredbendoura, County Auckland.

The country rock of the lease is siliceous granite, the whole area being covered with a dense forest of magnificent eucalypt growths. In the southern portion of the lease a small knob of aplite or pegmatitic granite outcrops. This is about 200 feet in diameter. The aplite contains numerous tiny holes or druses, and small thin flakes of molybdenite are scattered throughout the aplite as an original constituent, but without being concentrated into pipes, veins, or large patches at any one point. The average molybdenite content of the deposit is exceedingly low probably less than one-tenth of 1 per cent.

Aid was, however, granted the prospectors from the Government Prospecting Vote, as it was deemed advisable to give this new field a fair trial in the hope of discovering something of commercial value below the oxidised zone. With this aid a shaft was sunk 75 feet, and a cross-cut put out for a distance of 50 feet. From the stone mined, about seven or eight bags of low grade molybdenite ore were won by hand-picking. The stone tested by sinking and cross-cutting appears to be very similar to that exposed at the surface.

(*c*) M.L.5, 20 acres, and M.L. 9, 10 acres, both adjoining each other, and in Parish Bredbendoura, County Auckland.

According to Mr. P. J. Knox these leases both contain outcrops of molybdenite ore in siliceous or sandy granite, very similar in general character to the occurrences in M.Ls. 2, 4, 6, and 8.

7. *Summerell's Deposit.*—Portion 92, 40 acres, Parish Creewah, County Wellesley, private land. From 3 to 4 miles north-west by good road from the summit of Tantawanglo Mountain at Hammond's. The occurrence is in the sandy or siliceous granite of the Tantawanglo, and from specimens secured thence by my colleague, Mr. Leo Jones, and from descriptions also by Mr. Jones, the occurrence appears to be quite similar to the Tantawanglo deposits described above

8. *Tarlington's Deposit.*—M. L. 12, 20 acres, Parish Bredbendoura, County Auckland. The area is composed of sandy granite, with a few flakes of molybdenite. A fine stream of permanent water traverses this lease, and it is said that the main value of the area would be to provide water for the treatment of the ore mined in the adjoining leases.

9. *Taylor and Adams' Deposit.*—M.L. 10, 15 acres, Parish Bredbendoura, County Auckland

This deposit lies about three-quarters of a mile to the north from the summit of the Tantawanglo at Hammond's. The country is of sandy granite, and molybdenite flakes occur within it, apparently as an original constituent. The occurrence is similar in general character to the neighbouring Tantawanglo deposits. A shaft about 21 feet deep has been sunk on the outcrop.

TARANA. *See* Yetholme.

TAYLOR'S LODE. *See* Mole Tableland.

TEN MILE. *See* Deepwater.

THE TENTERFIELD DEPOSITS.

These are all unimportant, and include the various occurrences around Tenterfield itself, at Bungulla, and at the Bluff.

A long undulating valley, from 3 to 15 miles in width, extends from a point 8 miles north of Tenterfield to Bolivia. This valley is bounded in all directions by high, rugged walls. The valley rocks are composed of the " Blue Granite " of northern New England, the sphene-hornblende granite of New England, and, in a very subordinate degree, the molybdenite granite of Bolivia. To the north this valley wall consists of the sandy tin granites of Boonoo Boonoo and Stanthorpe districts; to the west the wall consists of the wolfram granite of the Mole River; to the south the tin and wolfram granite of the Bolivia cuttings bounds the valley; while to the east the high and rugged Main Divide cuts off the valley. The latter is formed of quartz-felspar porphyry. From a point one mile south of Tenterfield the Great Northern Railway follows the sphene-hornblende granite porphyry for a distance of 15 miles towards Bolivia, hugging its junction with the intrusive wolfram granite forming the rugged hills to the west. In these hills of coarse and fine sandy granite, numerous small deposits of molybdenite occur. In other places large dykes or tongues of the sandy granite have intruded the darker granites of the main valley floor described above, and in places these sandy granite tongues are traversed by tiny quartz veins containing scattered flakes of molybdenite.

Bluff (The) or Bluff Land.—Small deposits of molybdenite have been recorded from Portions 33 and 56, Parish Bluff Land, County Clive. The mineral appears to occur in granite.

Bungalla.—Several small deposits occur about 2 miles to the north-west of Bungulla Siding, in the fine sandy granite. The more noticeable of these which have been prospected are contained in James Chorley's and Michael Donnelly's C.L's., being Portions 32, 34, 46 and 78, Parish Strathearn, County Clive, and about 7 miles south-south-west of Tenterfield.

According to Mr. F. Chorley, the molybdenite occurs as flakes in small quartz veins through the sandy granite of both Chorley's and Donnelly's land.

Tenterfield.—Mr. C. S. Wilkinson, a former Government Geologist, reported as follows on a molybdenite ore from this locality* :—

> " A yellow, friable, ochreous mass of carbonate and oxide of bismuth, with quartz and molybdic oxide, from Tenterfield, contained bismuth 43·29 per cent., molybdenite 6·60 per cent."

(*a*) Town Common, 2 miles west of Post Office.—Occurrence : As flakes in tiny quartz veins ($\frac{1}{4}$ in. to $\frac{1}{2}$ in. wide) in large acid (" sandstone ") granite dykes exceeding 110 yards in width, traversing blue granite.

The dyke has, in cooling, contracted normally to its length, and the resulting fissures have been filled with quartz containing molybdenite (*vide* diagram illustrating chapter on " Hints to Prospectors ").

(*b*) Tenterfield Creek, $1\frac{1}{4}$ miles south of Post Office.—Occurrence : As flakes in an eurite dyke traversing alike the blue granite and sphene-hornblendic granite-porphyry. This occurrence, as also that described in (*a*), is interesting, inasmuch as it proves the molybdenite to be a segregation of the granite dykes themselves. The molybdenite flakes occur in small

* Mineral Products, New South Wales, 1882, p. 33.

lens-shaped pegmatitic secretions some 6 inches in length, shading off insensibly into the surrounding eurite. This type of dyke evidently represents a fairly well-hydrated magmatic excretion.

Small deposits occur also in the siliceous granites, in Portions 19, 22, 23, 28, 36, and C.P.L. 3,560, Parish Graham; in Portions 15, 101 and 102, Parish Glen Lyon; in Portions 2 and 7, Parish Addison; and in portion 6, Parish Ballandean, all in County Clive.

Thompson's (F.) Claim.—*See* Coronation Mine, under Deepwater.

(*c*) *Wallangarra.*—These occur in coarse and fine sandy granites near their intrusive contacts with basic granites and quartz-felspar porphyry. The deposits appear to be unimportant. They occur in Portions 27, 66 and 78, Parish Ballandean, County Clive.

Tingha Deposits.

Various unimportant occurrences of molybdenite within a radius of 20 miles from Tingha township are included under this heading.

1. *Elsmore.*—(*a*) The Elsmore Tin Mining Company (N.L.). Mr. J. E. Carne,* Government Geologist, in reporting upon this tin property at Elsmore Hill, Parish Anderson, County Gough, states that "the tin veins and the enclosing country also contain nests of wolfram, a little bismuth, molybdenite, and scheelite, the first-mentioned being the most common." The granite at this locality is a sandy and siliceous type, containing a great development of greisen.

Professor Liversidge† also mentions the occurrence of molybdenite with tinstone at the Elsmore and Newstead Mines.

(*b*) The New Cornwall Lode.‡—Portion 88, Parish Anderson, County Gough, "about 1 mile south of Elsmore, on south side of Macintyre River. Outcrop not visible. Shaft sunk 200 feet in the early seventies, soon after tin-mining began. . . . In the shaft spoil heap, the rotten granite still shows a little tin associated with molybdenite."

(*c*) Molybdenite has been found in small flakes in unpayable quantities in various old tin workings near Elsmore. Information supplied by Mr. Warden Perry.

Mr. Leo Cotton§ has also described the Elsmore tin and molybdenite deposits. According to this writer they consist of numerous small intersecting quartz veins in siliceous or tin-granite. Tin is the most important mineral in the deposits from a commercial point of view. "Wolframite," according to Mr. Cotton, "is found both crystallised and massive. . . . . The wolframite is not abundant, for very little is obtained when cleaning the tin for market. Its total weight is less probably than 1 per cent. of the tin present at Elsmore."

"Molybdenite occurs rather less abundantly than wolframite, and is to be found in small hexagonal flakes throughout the more siliceous parts of the veins."

(*d*) Applications by Mr. C. A. Sproull were made for Authorities to Enter on Portions 88 and 89, Parish Anderson, County Gough, to mine for molybdenite. Information supplied by Mr. Warden Perry.

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* Tin Mining Industry, N.S. Wales. Mineral Resources, No. 14, 1911, p. 310.

† Minerals of New South Wales, 1888, p, 71.

‡ J. E. Carne: Tin Mining Industry. Mineral Resources, No. 14, 1911, p. 220.

§ The Tin Deposits of New England, N.S.W. Procs. Lin. Soc. N.S. Wales, Vol. 34, 1909, pp. 733-781.

(*c*) Authorities to Enter have also been taken over portion of Portions 80, 83, 84 and 244, Parish Anderson, to seek for molybdenite. Very little prospecting work has been done.

2. *Howell.*—Conrad Mine.—Molybdenite reported as occurring in rare flakes in association with tin sulphide, galena, zincblende and quartz.

Graham's Claim.—M.L. 2, of 40 acres, on James Graham's Crown lease of 1,798 acres, Crown lands, Parish Tienga, County Hardinge, about 8 or 10 miles westerly from Tingha, and about 4 miles from Howell, near track to Bundarra. Molybdenite flakes in sandy granite. Very little prospecting work done.

Middle Creek.—Mr. C. S. Wilkinson, a former Government Geologist of this State, reported* that "in cutting a race through the granite of the Sydney Tin Mine, Middle Creek (between Tingha and Elsmore), a 'blow' or sudden expansion of quartz was exposed. In the quartz I found abundance of fluorspar in imperfect octahedral crystals of an amethystine or greenish colour. With this were also galena, iron pyrites, and molybdenite. One small specimen I obtained with all these minerals together."

Tin Pipe. *See* Yates' Pipes, under Kingsgate.

Tompkin's Gully. *See* Wilson's Downfall.

Torrington. *See* Mole Tableland.

Tonkins' Leases. *See* Gemalla and Yetholme.

Towrang. *See* Goulburn.

Turbet's (W. and R.) Claim. *See* Mount Metallic.

Twenty-Five Pipe. *See* Kingsgate.

Twenty-Five East. *See* Kingsgate.

Twenty-Five North. *See* Kingsgate.

Two-Mile Creek. *See* Wilson's Downfall.

Vaughan's Claim. *See* Rocky River.

Walker's Reefs. *See* Haystack Mountain, under Mole Tableland.

Wallangarra. *See* Tenterfield.

Wallendibby Mine. *See* Delegate.

Warrell Creek. *See* Nambucca.

Water Shaft. *See* Sachs of Kingsgate.

Waterson's (John) Claim. *See* Wilson's Downfall.

Waterson's (J. F.) Claim. *See* Wilson's Downfall.

Watkin's Claim. *See* Mole Tableland.

Watson's Lease. *See* Ardlethan.

Wayne and Hamilton's Claim. *See* Bolivia.

Webb's Lease. *See* Lowther, under Oberon.

Weir's (Hughie) Claim. *See* Boundary Creek, under Rocky River.

Wet Shaft. *See* Sachs of Kingsgate.

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* Mines and Mineral Statistics, N. S. Wales, 1875, p. 85.

The Whipstick Mines.

The Whipstick Mines lie near the main road connecting the townships of Panbula and Bombala. From the former the mines are 15 miles, and from the latter 36 miles by mountainous road. Bombala lies on the Monaro plateau, while Whipstick lies among the coastal ranges, the descent from the plateau being made by way of Big Jack Mountain, down which the road descends 2,200 feet in about 4½ miles. The mines may be approached also by steamer, the port being Merimbula, distant 18 miles from Whipstick, *via* Panbula. Another route is by motor for 75 miles from Cooma to Bega, by way of the Brown Mountain, thence by motor 22 miles to Panbula, and thence by coach to Whipstick.

The greater portion of the area for a radius of from 30 to 50 miles from Whipstick consists of Devonian sediments which have been intruded by granites, and over both of which, in the plateau area, Tertiary basalts have been poured.

The granite, which is mainly a dark hornblendic variety, containing numerous basic segregations, intrudes, but underlies, the Devonian sediments, the latter, with few exceptions, forming the summits of the hills and mountains. The granite at Whipstick itself, however, appears to be younger than the basic type of the district. From a consideration of the general arrangement of the massive conglomerate, grit, sandstone, and other beds composing the Devonian sediments, the granites, both basic and siliceous, appear to have their upper surfaces approximately parallel to the bedding planes of the enclosing sediments. On the other hand the granites of this great area may be seen to have burst through the old roof of sediments in various places, while sills are of common occurrence.

The description* of one portion of this region, namely, Wolumla, by Mr. J. E. Carne, Government Geologist, together with the sketch section accompanying his report, and reproduced on Pl. VIII, is characteristic of the Whipstick, Bega, and Candelo districts.

"The principal physical feature of the Wolumla district is an extensive granite valley almost completely surrounded by an elevated rim formed by the Wolumla, Black, Mumla, Bemboka, and Tantawanglo Ranges. The high lands on the north and west, towards Cobargo and Tantawanglo, are chiefly granite, while those on the south and east are mostly of sedimentary origin. The latter dip gently off, and away from, the granite of the valley.

"It would appear, from existing phenomena, that the granite originally rose to a considerable elevation over the site of the present valley, lifting a portion of the western edge of a great sheet of accumulated sediments from the coastal margin of the oceanic basin in which it had been deposited. During the uplift, which evidently was effected without any violent derangement of the strata, the basal bed (conglomerate) in contact with the granite was baked and hardened, quartzitic characters being developed in the sandy paste in which the pebbles are embedded. Extensive vertical joints in the conglomerate probably attest the strength of the tangential strain of the uplift, more than shrinkage caused by desiccation.

"Where the gold deposits occur a section of the uplifted strata has been tilted to a high angle, and partially engulfed in the granite magma, portions of which have been squeezed upwards through numerous joints and fractures in the sedimentary rocks, crushing and saturating them. The dynamic energy of the intrusions has also left its impress on the extruded granite,

* Annual Report, 1897, pp. 162–167.

for it presents a crushed and sheared appearance in the mass, and a waxy or chitinous aspect on closer view, owing to the felspars having been converted into a felspathic paste. . . . .

" Though apparently the granite originally formed a huge boss-like mass over the present Wolumla Valley, it was not isolated from the extensive outcrop trending southerly beyond the Victorian border, and westerly to the Monaro tableland.

" From the relative positions of the granite and the sedimentary rocks between it and the coast, it would appear that the original line of weakness marked by the former was coincident or closely parallel with a shore line of a Devonian sea. The sedimentary rocks betray their shallow marginal origin by massive conglomerates and ripple-marked sandstones. . . . .

" At Wolumla, the western margin of the beds caps the ranges, and with the one exception of Momsen's Hill, the dip is at a low angle eastward and southerly of the granite, which outcrops on the western flanks and in the gaps and valleys between the ranges and peaks. At Momsen's Hill, where the exceptional dip occurs, the beds have been tilted to an angle approaching the vertical. . . . .

. . . . . .

" Data collected in the Wolumla district not only confirm the previously-expressed opinion in my Pambula report that the quartz-felsite and rhyolite of Eden and Pambula are partially intrusive in the overlying Devonian series, but also demonstrate that the granite is likewise younger and intimately connected with the abovementioned acid eruptives."

Before describing the geology of the siliceous granite at Whipstick Mines themselves, the following note* by Mr. E. F. Pittman, A.R.S.M., Government Geologist, dealing with the bismuth deposits, may be here inserted :—

" *The Jingera Mineral Proprietary Mines.*—These mines are situated at Whipstick (near Wyndham), about fourteen miles to the west of Panbula, and are at the present time producing nearly all the bismuth raised in New South Wales. In their character and mode of occurrence the deposits are very similar to those of Kingsgate and Pheasant Creek, from which they are distant about five hundred miles. They consist of more or less cylindrical pipe-veins, which have a very irregular course and inclination, and which intersect granite rocks in proximity to their junction with slate. The filling of the pipes, however, instead of consisting entirely of quartz, as is the case at Kingsgate, is composed of a coarsely crystalline admixture of felspar and quartz, with a little mica, and occasional bunches of garnet rock. At least six of these pipes have been found, and they are all situated in proximity to a dyke (about four or five feet wide) of trachyte, which intersects the granite. The maximum diameter of the pipes is about fifteen or twenty feet, and the area within which they have, so far, been proved to occur is about two acres. The minerals which occur disseminated through the matrix are native bismuth, sulphide of bismuth, carbonate and trioxide of bismuth, and molybdenite. No wolfram has been found in these deposits. Quite recently a fine patch of native bismuth, weighing four hundredweight, was found associated with white quartz in one of the pipes, but as a rule the sulphide is the more common ore met with at a depth, while the carbonate and oxide occur near the surface.

* Mineral Resources, 1901, pp. 261–262.

"In 1891, shortly after the mines were opened, an isolated patch of extraordinarily rich ore was discovered close to the surface. It weighed three and a half tons, and was forwarded to Sydney for examination. After the parcel had been crushed and thoroughly mixed, a sample was assayed in the Laboratory of the Department of Mines, and yielded as follows :—

Metallic bismuth, 23·34 per cent.
Fine silver, at the rate of 1,108 ounces per ton.
Fine gold, at the rate of 11 dwt. 23 gr. per ton.

" Further prospecting failed to reveal the source whence this apparently isolated bunch of ore was derived. One or two instances, however, of narrow but highly argentiferous veins have been discovered, and in 1893 the company exported thirty-one tons of argentiferous bismuth ore, which yielded three and a half tons of metallic bismuth, twelve ounces of gold, and 6,107 ounces of silver. An auriferous quartz reef also occurs in proximity to the bismuth pipes, and four tons extracted from this are said to have yielded at the rate of an ounce of gold per ton; on being followed down, however, the stone became poorer, and ceased to be payable.

" The mines have been worked principally by a tunnel which has been driven in a straight course, and when pipes have been intersected by it they have been followed laterally, or vertically, as the case might be. From one of these pipes more than six hundred tons of ore have been extracted."*

General Geology.—The Whipstick mines, as mentioned earlier by Mr. E. F. Pittman, occur in granite near its contact with sedimentary rocks.

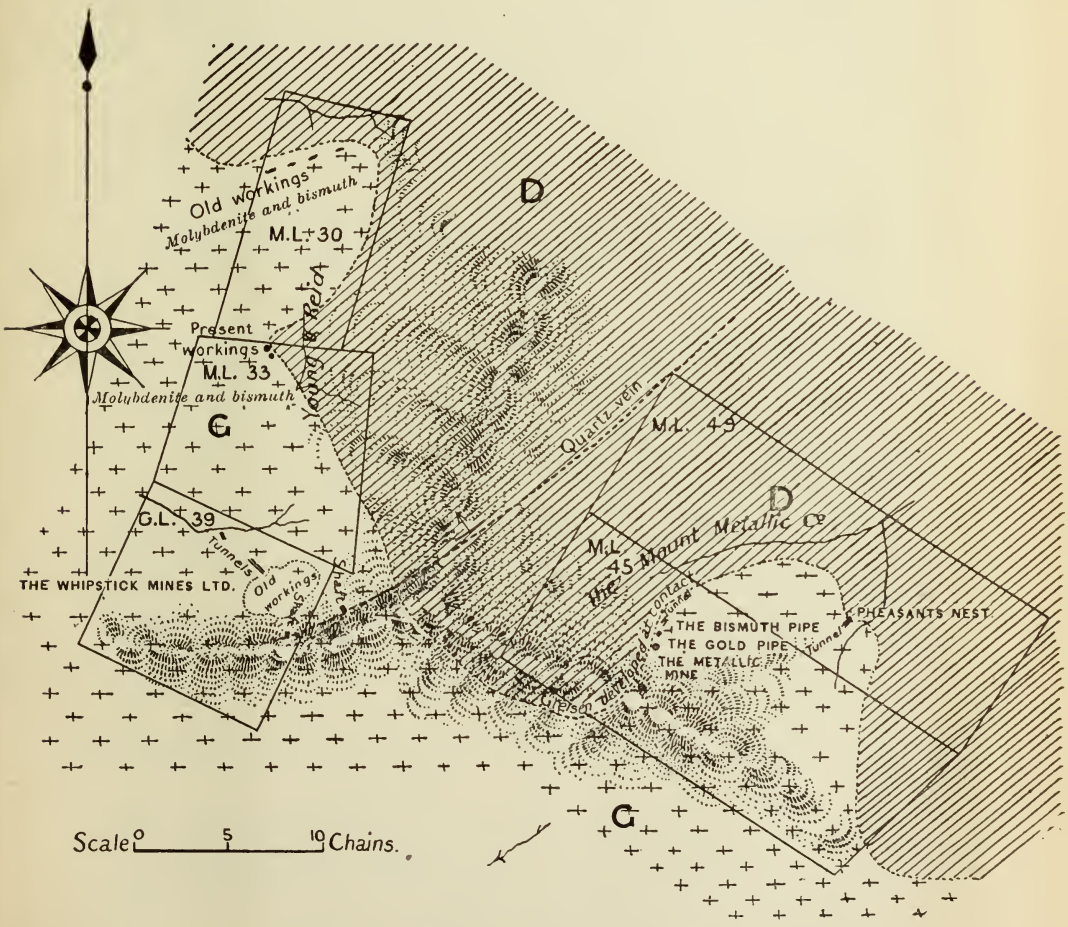
Unlike the granite of Bega, Bemboka, Candelo, Rocky Hall, and the Big Jack Mountain, which are dark or basic types, containing much hornblende in stout crystals, and many dark inclusions, the granite of Whipstick is light-coloured and siliceous in nature The vegetation, however, is not so starved and stunted as might be expected from a sandy granite type such as the one under consideration. The general absence from Whipstick of stunted growths, which botanists usually associate with such poor soils, is to be explained in part by reason of the abundant and constant rainfall and in part also by reason of the rugged nature of the country, which consists of deep sheltered gorges separated by high narrow ridges. Eucalypts of immense height and magnificent appearance form dense forest growths on the slopes, while brush growths of myrtles, tree ferns, and other plants, abound in the lower portions of the ravines. The main portion of the larger vegetation consists of the black ash (*Eucalyptus Sieberiana*), mountain ash (*E. Delegetensis*), cut-tail (*E. fastigata*), stringybark (*E. eugenioides, E. Muelleriana, E. capitellata,* and *E. obliqua*), peppermint (*E. amygdalina*), white gum (*E. viminalis*), *E. radiata,* white hickory (*Acacia melanoxylon*), hickory (*A. penninervis*), golden wattle (*A. longifolia,* in thickets), sunshine wattle (*A. discolor*), *A. decurrens, A. stricta,* lillypilly (*Eugenia Smithii*), dead finish (*Cassinia*), everlastings (*Helichrysum*), wild holly (*Oxylobium trilobatum*), and other types.

The granite is coarse in texture, and consists of large and abundant grains of quartz associated with pink felspar and abundant plates of white mica. Near the contact of the granite with the Devonian sediments the white mica

* Mineral Resources of New South Wales. 1901, pp. 261-262.

is much more abundant than in the main body of the rock, and, in certain places the mica content of the granite is such as to give the appearance of a mass of white mica. The sediments have been classed as Devonian by their lithological resemblance to those beds in the neighbourhood which have been proved to be of Devonian age by Mr. J. E. Carne. Moreover, by filling up the valleys of erosion in the ranges in imagination the sediments of the Whipstick Mountain may be inferred to have been continuous, at some former time, with the Devonian slate, sandstone, and conglomerate beds mentioned by Mr. Carne.* These sediments occupy the higher portion of Whipstick Mountain, while the siliceous granite forms the lower and middle portions to the west, south, and south-east of the mines, as may be seen on the accompanying map and section across the area. (Pl. XXII, and Fig. 27.)

PLATE XXII.



Parish of Wyndham, County of Auckland.

D—Altered claystone. G—Siliceous granite.

* Annual Report, 1897, p. 163.

Although the main granite and slate contact is well defined, nevertheless numerous small patches of sediments occur as isolated residuals upon the granite at slight distances from the main mass of the sediments. This feature is well illustrated in Young and Reid's leases. The sediments have been intruded by the granite, as may be seen by the contact alteration of the Devonian sandstones to quartzites, of the claystones to knotted slates, by the development of minerals such as mica within the granite near the contact, and by the peculiar geological occurrence of the "pipes" at Whipstick themselves. The granite may have a laccolithic development over restricted areas.

Numerous dykes of varying composition intersect the granite, and reference is made to these in the description of the mine workings.

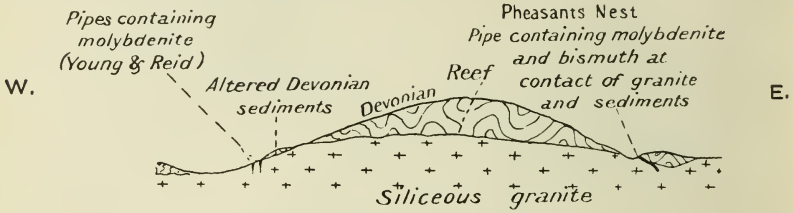


Fig. 27.

Sketch section across the Whipstick Mining area. The section illustrates the flatness of curvature of the granite surface, and the occurrence of the molybdenite pipes at and near the contact of granite and altered sediments.

The accompanying figures illustrate some of the main geological features at and near the mines. The granite and slate contact forms a surface which is fairly flat, and the molybdenite deposits appear to occur close either to a present or former roof of altered sediment, and, what is significant, there is a suggestion from the mining workings themselves that the "pipes" have branched as they approached the sedimentary roof. (*See* Map.)

A study of the outcrops in the Mount Pleasant, the Metallic, the Whipstick Mines, Limited, and Young and Reid's blocks does not indicate that each group of pipes is related to any definite geometrical plane, nevertheless a study of the lower workings of the Whipstick and Metallic Mines indicates that each group of pipes, considered separately, commenced at a considerable depth below the intrusive granite contact from a common source and that as the pipes approached the granite margin they branched in various directions from the single lower source.

Mineralogical Notes on the Pipes.—The pipes of the Whipstick Mines, Limited, and the Metallic Mines may be taken as types of the deposits in the locality.

In the Metallic group the Gold Pipe outcropped as a manganese gossan and a rock composed, in the main, of white mica in fairly coarse flakes. This mass was of the nature known to miners as kindly, being soft, friable and drusy. So much manganese was present in this, and other outcrops, that specimens have been forwarded to the Departmental Laboratory for analysis as manganese ores.

Gold was found in this outcrop in quantities sufficiently rich to repay working expenses, but little or no bismuth appears to have been noted. In the bismuth pipe, or branch, of the same mine the outcrop consisted of a mass

of manganese gossan with molybdic and bismuth ochre. At a depth from 20 to 30 feet below the surface the sulphides of molybdenum and bismuth were found, and here the manganese gossans disappeared almost entirely, their place being taken by a transparent granular form of garnet, occurring in large and small bunches scattered throughout an altered form of siliceous granite. This altered granite forms the greater portion of the pipes of Whipstick. In places the texture of the granite has not been altered in any marked degree, but silicification has gone on to such an extent that much of the felspar content has been replaced by granular quartz, white mica has been developed abundantly in places, while molybdenite in crystals and rosettes, native bismuth, sulphide of bismuth, and garnet, both massive and crystalline, have been developed throughout the granite. This apparent alteration seems to have been most intense at the more central portion, or longer axes, of the pipes, and it has died away in such a manner as to have caused the pipes to become large and approximately elliptical in cross-section. Beyond these limits there is a gradual transition into the unaltered granite of the country.

The No. 3 pipe of the Whipstick Mines had a massive cap of manganese gossan, which disappeared at a vertical depth of 40 feet, approximately, from the surface. At this depth the manganese gossan gave place to altered granite containing large patches of reddish garnet. Molybdenum and bismuth ochres occurred abundantly below the surface, but it was not until a depth of 30 to 40 feet had been reached below the surface that the clean sulphides were found. A similar association of minerals is reported from the upper portion of the No. 1 pipe, which outcropped on the steep hillside below the No. 3 pipe. In both of these pipe branches the rock was very similar in appearance to that of the pipes of the Mount Metallic Mine in the vicinity.

At a considerable depth below the outcrop of No. 3 pipe or branch, other pipes or branches were worked. The ore in these resemble that in Nos. 1 and 3 branches. Among these branches or pipes may be mentioned No. 2, or the Main Pipe, Nos. 5 and 6. (*See* accompanying Maps.)

On the sketch map of the plans and sections of Whipstick Pipes, in " Plan at F " the No. 6 pipe has been labelled No. 2. This is incorrect, because the No. 2 pipe has disappeared at this level F.

At the No. 2 or upper level also, the branch, known as the Pilot, was seen. This consisted of a tortuous cylinder of quartz, brittle and white, and quite distinct in appearance from the pipes of altered granite associated with it. A ring or zone of garnet rock surrounded the quartz axis of the Pilot for a width varying from 2 to 12 inches. The Pilot does not appear to have contained molybdenite or bismuth in considerable quantities.

At a depth of 215 feet below the lower or No. 1 Level (*see* Maps), the pipes known at the present time are only two in number and are close together. The main pipe, No. 2, is here the usual altered granite, consisting in places of a granular aggregate of quartz, with a slight admixture of felspar in the central portions. At a depth of 260 feet below the No. 1 or low-level tunnel the No. 2 Pipe is composed of a very siliceous granite with garnet.

At a depth of 215 feet below No. 1 tunnel, a garnet pipe was found in contact with the No. 2 or Main Pipe. This was found to be about 25 feet in longer diameter of cross-section, and perhaps 20 feet in greatest width in cross-section. Instead of being composed of granite it was found to be a mass of granular garnet, fine in texture, and containing large patches of quartz with native bismuth, sulphide of bismuth, telluride of bismuth or Joseite, and molybdenite.

Appended are analyses of both pipe granites and the Joseite by Messrs. H. P. White and W. A. Greig, of the Departmental Laboratory, under the supervision of Mr. J. C. H. Mingaye. The granite of the country contains about 74 per cent. silica.

2515.—Biotite granite from Whipstick Mine.
2516.—Granite from Whipstick Mine.
3336.—Muscovite granite, from Whipstick Mine, near mouth No. 1 tunnel, 450 feet from pipe.

	2515.	2516.	3336.
Chemical Composition.	Per cent.	Per cent.	Per cent.
Silica	83·54	87·66	75·02
Alumina	9·13	7·32	13·77
Ferric oxide	0·50	0·30	1·40
Ferrous oxide	0·36	absent	0·27
Magnesia	0·30	0·08	0·04
Lime	0·46	absent	0·12
Soda	3·51	3·58	3·29
Potash	1·14	0·20	4·78
Water (100° C.—)	0·10	0·02	0·07
Water (100° C.+)	1·14	0·36	1·17
Carbon dioxide	absent	0·05	absent
Titanium dioxide	*trace	absent	0·30
Zirconia dioxide	absent	absent	absent
Phosphoric anhydride	0·05	0·02	0·03
Sulphur trioxide	0·04	absent	absent
Chlorine	0·04	*trace	absent
Fluorine	absent	absent	absent
Sulphur	absent	0·16	absent
Chromium sesquioxide	absent	absent	absent
Nickel and cobalt oxides	absent	absent	absent
Manganous oxide	absent	*trace	0·02
Barium oxide	absent	*trace	absent
Strontium oxide	†present	absent	absent
Lithia	absent	†present	†present
Vanadium oxide	absent	absent	absent
Copper	absent	absent	absent
Bismuth	absent	0·54	absent
Lead	absent	absent	absent
Molybdenum	*trace	*trace	absent
	100·31	100·29	100·22
Specific gravity	2·666	2·646	2·633

* Less than 0·01 per cent. † Spectroscopic reaction only.

2515: Gold, nil; Silver, a trace
2516: Gold, nil; Silver 4 dwt. 8 grs. per ton

2515—Analysis by W. A. Greig.
2516— ,, H. P. White.
3336— ,, H. P. White.

2050.—Mineral picked from native bismuth with telluride and sulphide of bismuth in glassy quartz and garnet material. The analysis indicates the mineral to be Joseite. Analysis by J. C. H. Mingaye.

	Per cent.
Bismuth	82·92
Tellurium	9·16
Selenium	trace
Sulphur	6·19
Manganese	0·77
Iron	0·47
Gold	absent
Silver	absent
Insoluble matter	0·32
	99·83

Specific gravity—(1) 7·793; (2) 7·688

Origin of Pipes.—From a knowledge of these facts, combined with a study of the accompanying plans and sections, it would appear that the pipes have been formed subsequently to the general consolidation of the granite in its more marginal portion ; that each group of pipes has been formed from some centre within the cooling, but still hot, granite, that the pipes have branched as they approached the surface; that the alteration of the granite in part, if such alteration did occur, proceeded from a series of tortuous lines now forming the longer or vertical axes of the pipes; and that the alteration has been such as to introduce much silica, manganese, sulphur, and perhaps water, with certain amounts of molybdenum, bismuth, tellurium, selenium, gold, silver, and iron, into the siliceous granite.

It has been stated already that there is no trace to the unaided eye of joint planes which might have afforded a passage for ascending hot vapours carrying minerals in solution, nevertheless the evidence of the collinearity of the main axes of the Nos. 1, 2, and 3 pipes is so striking, as is also the evidence of the transition from ore to granite in radial directions as measured from the longer axes of the pipes, together with the " step-and-tread " nature of certain pipes, as may be seen for No. 3 Pipe in the map, that it appears justifiable to infer the action here of vapours, expelled from the cooling granite, containing molybdenite, bismuth, silica, manganese, and other minerals, all exceedingly mobile under the action of great heat and pressure. These vapours may be inferred to have been working their way from a region of high pressure, namely, the heated granite, to a region of less pressure, namely, the cooler sediments near the contact zone. The penetrative powers of the vapours under these conditions were such that they could ascend planes or zones of weakness in the cooling granite not visible necessarily to the naked eye, especially at points where these planes had been intersected by microscopic cross-joints. These ascending vapours would naturally find less resistance to their progress as they neared the granite contact with the slate, and thus branching might be expected, with deposition of the molybdenite, bismuth, gold, silver, and other contents in the less heated granite margin, much in the same way that sulphur, copper, bismuth, zinc, and certain other minerals may be deposited from fumes in the cooler portions of chambers or chimneys leading from a smelting furnace.

This idea of the pipes being due to replacement agencies is also suggested by the very variable degree of alteration, or mineral composition, which the pipes present, not only in the various members, but in the same individual. Thus it is remarkable how a large pipe, as much as 25 feet in diameter, may disappear overhead as a mere thread, or a tiny joint carrying molybdenite, or how such a deposit may appear to disappear as an insignificant and irregular body when traced in a horizontal direction, while it may reappear in another place as a great impregnation. The Pilot, the Nos. 1 and 2 pipes of the Whipstick, and the Gold and Bismuth pipes of the Metallic may be taken as types of this supposed variable alteration of granite by vapours containing various elements in solution. The Gold pipe of the Metallic Mine appears to represent an alteration of the felspars of the granite to mica; the Nos. 1 and 2 pipes appear to represent stages more advanced than the introduction of mica. In these deposits the mica does occur, but only in subordinate amount. A marked silicification is noted in these pipes, and a considerable development of garnet. In the Pilot, on the other hand, an alteration, almost completely to quartz, may be noted, the core and main portion of the deposit consisting of white brittle quartz, while the margin, or

collar, is of garnet, or rarely of mica. In the opinion of the Writer, the Pilot consisted, at one period, of a granite containing about 74 per cent. silica; at a later period vapours ascended along intersecting vertical joints of very small dimensions. These altered the granite surrounding the joint intersections in a manner such that their intensity decreased in a radial direction within any horizontal section. They gradually replaced the felspars of the granite by fine flakes of hydrous mica. These, in turn, were replaced by garnet masses and by silica, which became more or less continuous with the quartz grains originally in the granite. This granular quartz, garnet and mica admixture gradually became replaced at and near the linear core by a white brittle quartz, the latter being encircled by a collar of garnet in places, of hydrous mica in other places, each dying away into an encircling zone of granite, showing felspars invaded by mica specks and flakes. This association in the Pilot does certainly suggest a decreasing intensity of alteration in granite in a horizontal direction from the general direction of the twisted linear core of the pipe.

History of Whipstick Mines.—The following notes on the earlier history of the Whipstick Mines have been derived in part from Mr. Pittman's* notes on the field, in part from information supplied by Messrs. R. Vernon Saddington and R. Y. Medcalf, and in part from notes supplied by Mr. W. H. Yates, of Kingsgate.

Bismuth ore appears to have been discovered in 1891 on the slope of the Whipstick Mountain, overlooking Merimbula. Eight leases, totalling 203 acres in area, were taken up then at this locality by the Great Jingera Proprietary Silver-Mining Company.

According to Mr. E. F. Pittman,† it appears that "in 1891, shortly after the mines were opened, an isolated patch of extraordinarily rich ore was discovered close to the surface. It weighed three and a half tons, and was forwarded to Sydney for examination. After the parcel had been crushed and thoroughly mixed, a sample was assayed in the laboratory of the Department of Mines, and yielded as follows :—

Metallic bismuth, 23·34 per cent.
Fine silver, at the rate of 1,108 oz. per ton.
Fine gold, at the rate of 11 dwt. 23 gr. per ton.

"Further prospecting failed to reveal the source whence this apparently isolated bunch of ore was derived. One or two instances, however, of narrow, but highly argentiferous veins have been discovered, and in 1893 the Company exported thirty-one tons of argentiferous bismuth ore, which yielded three and a half tons of metallic bismuth, twelve oz. of gold, and 6,107 oz. of silver. An auriferous quartz reef also occurs in proximity to the bismuth pipes, and four tons extracted from this are said to have yielded at the rate of an ounce of gold per ton."

The accompanying notes on the history during the period 1891–1896 were supplied by Mr. W. H. Yates, of Kingsgate : "Near the summit of the spur or range (about 1,000 feet above the flats at the foot), a small excavation, about 4 feet deep by, say, 6 feet by 6 feet, had been made in the soft decomposed surface granite, which showed for a width of, say, 2 feet, a considerable quantity of bismuth-carbonate in fine grains, well disseminated, and said to be rich in silver.

* E. F. Pittman. Mineral Resources, 1901, p. 262. † *Op. cit.*, p. 262.

"A large area of land in 40-acre mineral blocks had been taken up. Seven or eight of these blocks, including the rich find near the summit, were amalgamated and held by a syndicate. This was the position in September, 1891.

"The rich ore near the summit was followed on its dip for about 10 feet, where it disappeared abruptly against a well-defined quartz reef running north-east and south-west. The miners were unable to trace the ore beyond this, and horizontally the impregnation did not extend. About four tons of ore were obtained here, averaging about 24 per cent. of bismuth and 1,200 ounces of silver a ton. This ore was sent to Germany. After this the Company sank 30 or 40 feet on the quartz reef, but found no bismuth, although it was said to contain silver and gold in payable amount. A tunnel was then driven into the hill in a south-east direction to cut the quartz reef about 100 feet below the outcrop whence the rich ore patch had been taken. The estimated length of this tunnel, prior to driving operations, was 300 feet. At a point 115 feet along the tunnel from its mouth, granite carrying bismuth was cut unexpectedly. This formation was found to continue into the hill, in patches, for 30 feet, the bismuth occurring as sulphide disseminated in particles thickly through portions of the granite. Molybdenite occurred also in this material. It is stated that 50 tons of ore containing 10 per cent. of bismuth were obtained during 1892.

"The tunnel was continued, and at a distance of about 320 feet from the mouth the 'Quartz Reef' was cut, and was driven on its course south-west for 60 feet, but no bismuth was found in it. [It was a well-defined vein three feet in width.] The tunnel was driven a farther distance of 80 feet, making 400 feet in all, but nothing of commercial importance was found by this extra work."

"About March, 1893, the Company ceased operations entirely and the mine lay idle for about eighteen months."

The history of Whipstick for a considerable period subsequent to 1893 has been supplied by Messrs. R. Vernon Saddington and R. Y. Medcalf. In 1895 the mine was acquired by the late Mr. R. Saddington, in conjunction with Mr. E. W. Bathurst. A considerable amount of money was spent in developing the mine. Bismuth was sought primarily, and silver secondarily, while molybdenite, which occurred rather abundantly, was regarded as an impurity, inasmuch as it had no commercial value at that time. Nevertheless the bismuth had to be free from molybdenite admixture. At that time the ore was hand-dressed. Much of the ore contained as much as 10 per cent. bismuth, while small lots also contained silver as high as 1,000 to 1,200 oz. a ton.

Arrangements were made, at a subsequent date, to supply Messrs. Elliot Bros. with 3,000 tons of bismuth ore, which was to be converted into metallic bismuth by the buyers. Difficulties, however, were experienced in fulfilling the conditions of the contract, and at last Elliot Bros. took the mine on tribute until the amount promised under terms of the original contract should have been mined.

In 1897 the existence of a quartz reef, containing gold, was reported from the locality. This vein was prospected along the outcrop for a distance of about 100 yards. The gangue was a true quartz, slightly honeycombed, and crystallised in places. The gold was reported to be of heavy and shotty nature.

After the termination of Elliot's tribute arrangements were made with Messrs. Charles Markell & Company, with the executors of the late Mr. R. Saddington, and with Messrs. Elliot Bros. to work the mine afresh and conjointly. The "International Mines Ltd." was thus formed, with a capital of £10,000 in 10,000 shares of £1 each. Mining was carried on with varying fortunes for a time, when, owing to the metal contents of the ore being won at the time dropping to about 0·60 per cent. bismuth, the Company ceased mining operations at Jingera. During the term that this Company was producing ore, the richer portions were sent to the works at Balmain, belonging to Elliot Bros. The low grade ore was concentrated before being despatched to Balmain to be converted to refined bismuth. A portion of the refined product was used locally, but the greater portion is said to have been sent to Messrs. Johnson and Matthey, in England.

The accompanying notes dealing with the history of Whipstick during the past few years have been supplied by Mr. J. E. Scantlebury.

The lease taken up by Mesrs. Markell & Company lapsed a few years ago, and it was then taken up by Messrs. T. A. Schafer and H. Robertson. In 1912 they raised 63 tons of molybdenite ore, valued at £500. The ore was hand-dressed and despatched to Germany for treatment.

Messrs. Schafer and Robertson then gave a working option to a small group of mining men. During a period of twelve months the option had the right to remove ore either from the mine or the dumps on the basis of a 5 per cent. royalty. This syndicate, so-called, was merged subsequently into a company of 24,000 shares of 10s. each, of which 18,000 are said to have been issued and 6,000 held in reserve. This company is known as the Whipstick Mines, Ltd.

Production.—It is not possible to obtain a complete statement as to the production of molybdenite and bismuth from the various Whipstick Mines. In the earlier days of mining at this locality the molybdenite was cast aside for reasons already set forth. Moreover, the producers of bismuth maintained a secretive policy, as far as possible, concerning the output and the price of this metal. The accompanying return has been compiled from the various official publications, but at the best it is only a statement which is far from being complete.

The Whipstick Mines, Ltd.—In 1892 the Whipstick Mines, known then as the Great Jingera Silver-Mining Company, "sent away to Europe 31 tons of argentiferous bismuth ore, which gave a return of 3½ tons of bismuth, 12 oz. gold, and 6,107 oz. silver, of a total value of £2,343."*

"In the Annual Report, 1897, page 42, it is pointed out that 1,430 tons of ore were raised during that year, of which 146 tons were sold and exported. The estimated value of the bismuth sold was £3,100, and that of the silver associated with the bismuth, £264."†

"Mr. G. C. Elliot reports having raised 576 tons of ore from his mine at Whipstick, Jingera, during the year, which were treated in Sydney, some 10 tons of bismuth being produced."‡

In 1901, 1902, 1903, it is reported that 20·8 tons, 10·15 tons, and 21·75 tons, respectively, of bismuth concentrates were produced in the State, the greater portion of which amount is said to have been won from Jingera (Whipstick).

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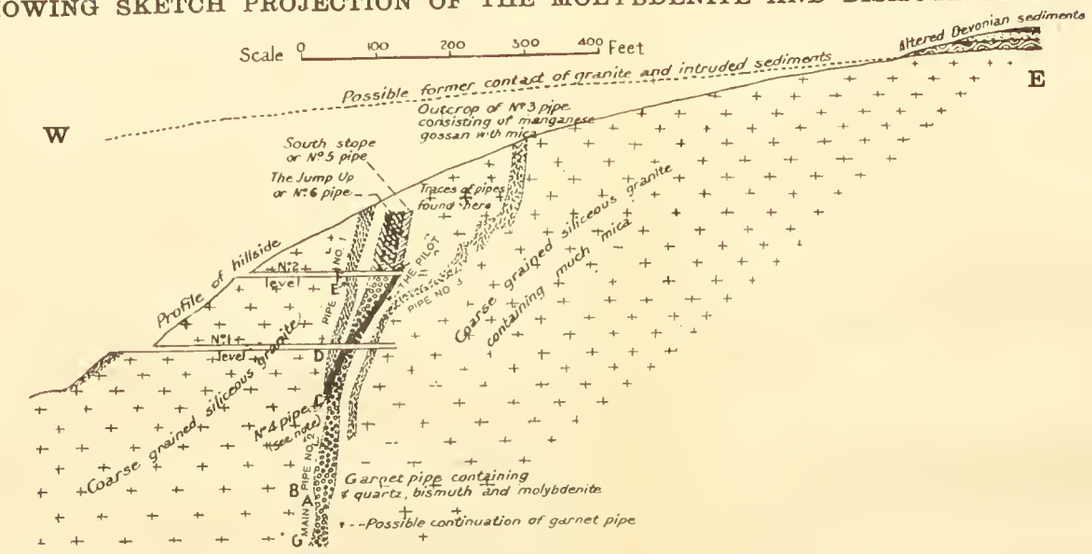
* J. A. Watt. Bismuth Ores of New South Wales. Mineral Resources, No. 4, 1898, p. 11.
† J. A. Watt. Mineral Resources, No. 4, 1898, p. 11.
‡ Annual Report, 1900, p. 64.

SKETCH PLANS AND SECTIONS

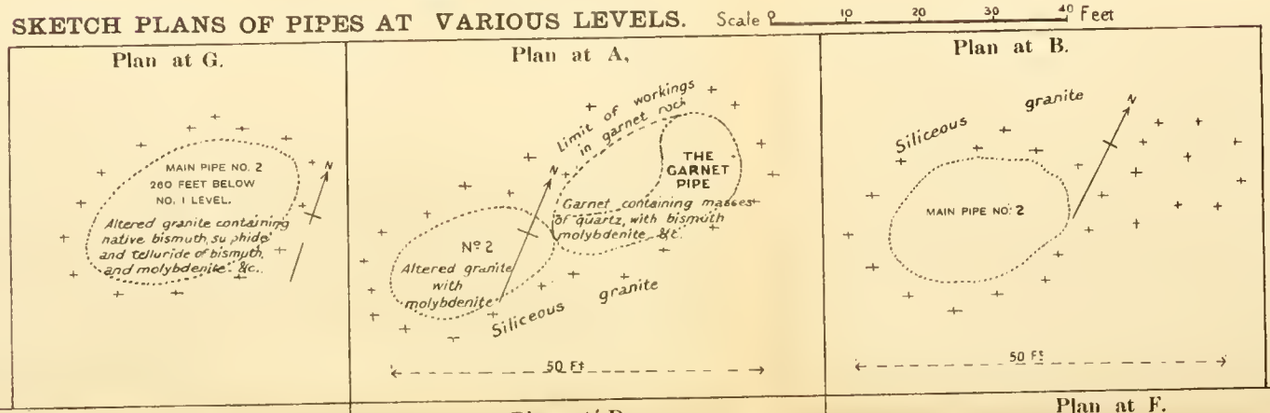
WHIPSTICK MINES LIMITED

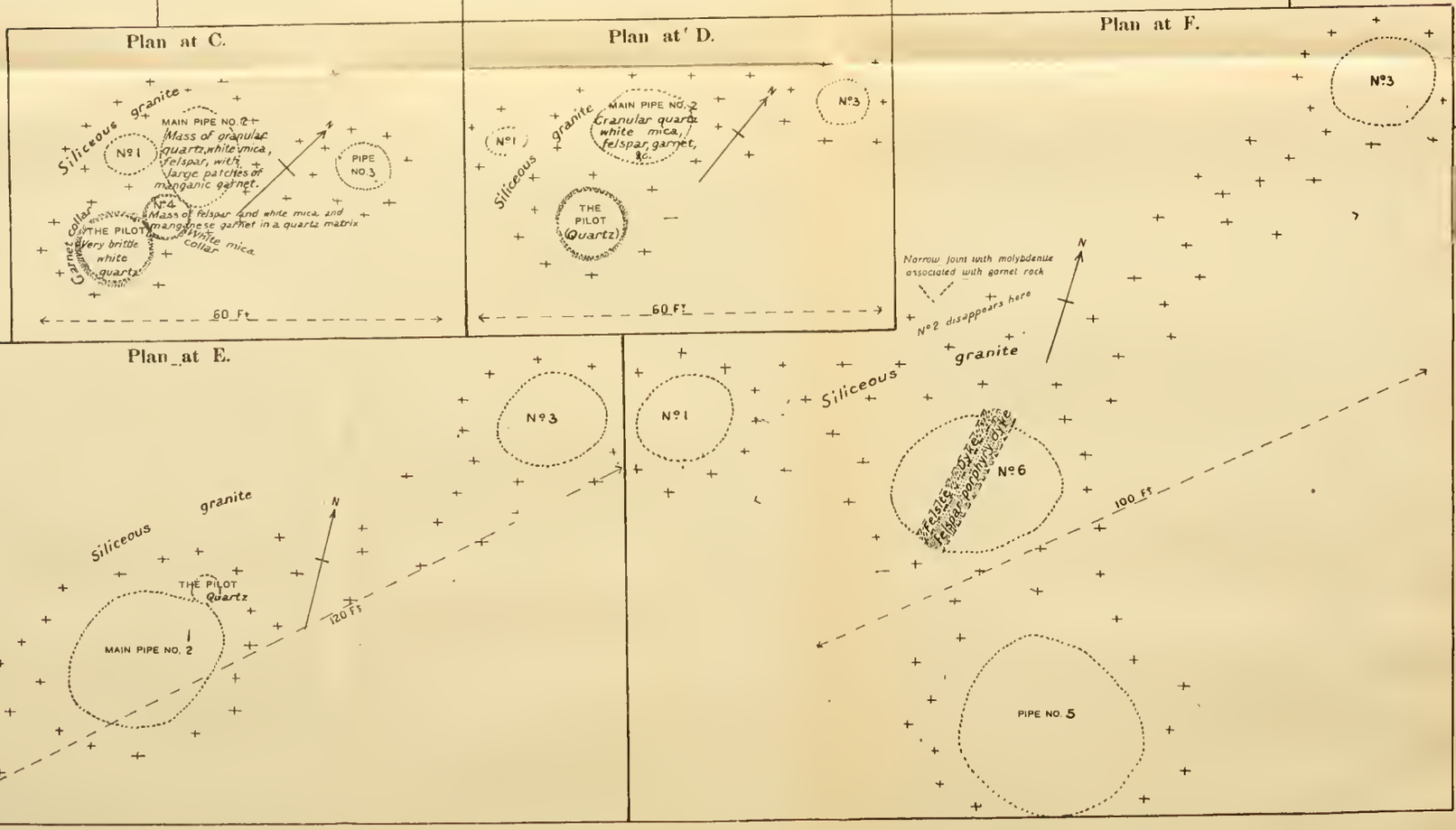
PARISH OF WYNDHAM, COUNTY OF AUCKLAND.

SECTION SHOWING SKETCH PROJECTION OF THE MOLYBDENITE AND BISMUTH PIPES


Scale 0 100 200 300 400 Feet
Altered Devonian sediments
Possible former contact of granite and intruded sediments
W
E
Outcrop of No 3 pipe consisting of manganese gossan with mica
South slope or No 5 pipe
The Jump Up or No 6 pipe
Traces of pipes found here
Profile of hillside
No 2 Level
No 1 Level
Coarse grained siliceous granite containing much mica
No 4 Pipe (see head)
Coarse grained siliceous granite
Garnet pipe containing quartz, bismuth and molybdenite
Possible continuation of garnet pipe
MAIN PIPE NO 2
PIPE NO 3
THE PILOT

SKETCH PLANS OF PIPES AT VARIOUS LEVELS. Scale 0 10 20 30 40 Feet


Plan at G.
MAIN PIPE NO. 2
260 FEET BELOW NO. 1 LEVEL.
Altered granite containing native bismuth, sulphide and telluride of bismuth, and molybdenite &c.
Plan at A,
Limit of workings in garnet rock
THE GARNET PIPE
Garnet containing masses of quartz, with bismuth molybdenite &c.
No 2
Altered granite with molybdenite
Siliceous granite
50 Ft
Plan at B.
Siliceous granite
MAIN PIPE NO. 2
50 Ft



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PARISH

SECTION SHOWIN

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In 1904, bismuth concentrates to the amount of 40·3 tons were produced in the State. A large proportion of this came from the International Mines, Ltd. (Whipstick Mines, Ltd.)

1905.—1,964 tons of bismuth ore. Value, £5,320.

1907.—372 tons of bismuth ore. Value, £2,504.

1908.—4½ tons of bismuth ore. Value, £60.

1909.—Return unknown.

1910.—Schafer and Robertson (Whipstick Mines, Ltd.) raised 60 tons of ore, which was not treated in 1910.

1911.—3½ tons bismuth concentrate. Value, £479.

1912 { 68 tons bismuth ore. Value, £859.
63 tons molybdenite ore. Value, £500.

1913 { 4 tons bismuth concentrate. Value, £739.
16 tons molybdenite concentrate. Value, £6,400.

1914 { 36 tons bismuth ore. Value, £1,742.
9 tons molybdenite concentrate. Value, £5,000.

1915 { 17 tons bismuth ore.
12 tons molybdenite. Valued at £6,000.

1916 { Till 30th June about 12 or 15 tons molybdenite.
4 tons bismuth.

The Mount Metallic Mine.

1904.—850 tons of ore raised, yielding 5·05 tons bismuth concentrate, valued at £2,262.

1905.—290 tons bismuth ore. Value, £544.

1906.—230 tons bismuth ore. Value, £460.

1914 { 2¾ tons bismuth concentrates. Value, £201.
Molybdenite, not known.

1915 { 20 tons bismuth ore said to contain 3 tons bismuth, not known.
20 tons molybdenite ore, not known.

The early returns of Whipstick were for bismuth only, but they are recorded here in order to emphasise the amount of molybdenite rejected, inasmuch as the molybdenite content of the ore appears to be comparable with that of the bismuth.

Descriptions of Mines.

1. The Mount Metallic Mines.—These embrace M.Ls. 45 and 49, of 40 acres approximately, Parish Whipstick, County Auckland. This area embraces the old mines known as the Mount Metallic and the Pheasant's Nest. The deposits consist of mica, garnet, and granite, pipes with free quartz in large patches, all occurring either at or near an intrusive granite contact with altered Devonian claystone. All the deposits outcrop on a very steep hillside covered with brush growths. Between the outcrops of the old Metallic Mount and the Pheasant's Nest there are indications of other pipe outcrops which may represent points of connection with the Pheasant's Nest.

The prospectors of the Metallic Mine came upon a patch of manganese gossan, with much white mica, forming a small circular outcrop on the hillside near the main granite and claystone junction. This was found to

contain gold. The deposit dipped steeply into the hill, and was followed with ease to a depth of about 80 feet by reason of its pronounced content of mica and gold. At this depth the pipe, or branch, proper was lost temporarily, but by following an irregular impregnation in a sub-horizontal and circuitous direction the prospectors are said to have come upon a bismuth pipe which rose steeply to the surface with a strong outcrop of garnet rock. This pipe, or branch, was not traced to a depth greater than about 60 feet below the surface. Prospecting was continued in various horizontal directions by means of certain "indications," and this led to the exposure of various irregular impregnations. Finally, Mr. Schafer, a prospector, was led to a pipe containing both bismuth and molybdenite, which dipped steeply in a fairly uniform direction. This pipe was prospected to a depth of about 100 feet below the point at which the gold pipe had been lost, but at a considerable distance in a horizontal direction. The prospects of this pipe I was unable to ascertain, inasmuch as there was a considerable amount of water in the bottom during my visit in 1915. A tunnel has been put in the hillside at the level of the base of the gold pipe so as to work all the connected openings.

The Pheasant's Nest deposit is a pipe which occurs at the actual contact of the granite and the overlying and silicified sediments. The workings are about 240 feet in length as measured along the dip, which is probably less than 1 in 2.

Several openings were made here in the early days, one a few yards below the present entrance and one a little to the right as the entrance is faced. From the outcrop and from the portion of the deposit near the surface, it is reported that the early workers found large patches of very rich bismuth ore.

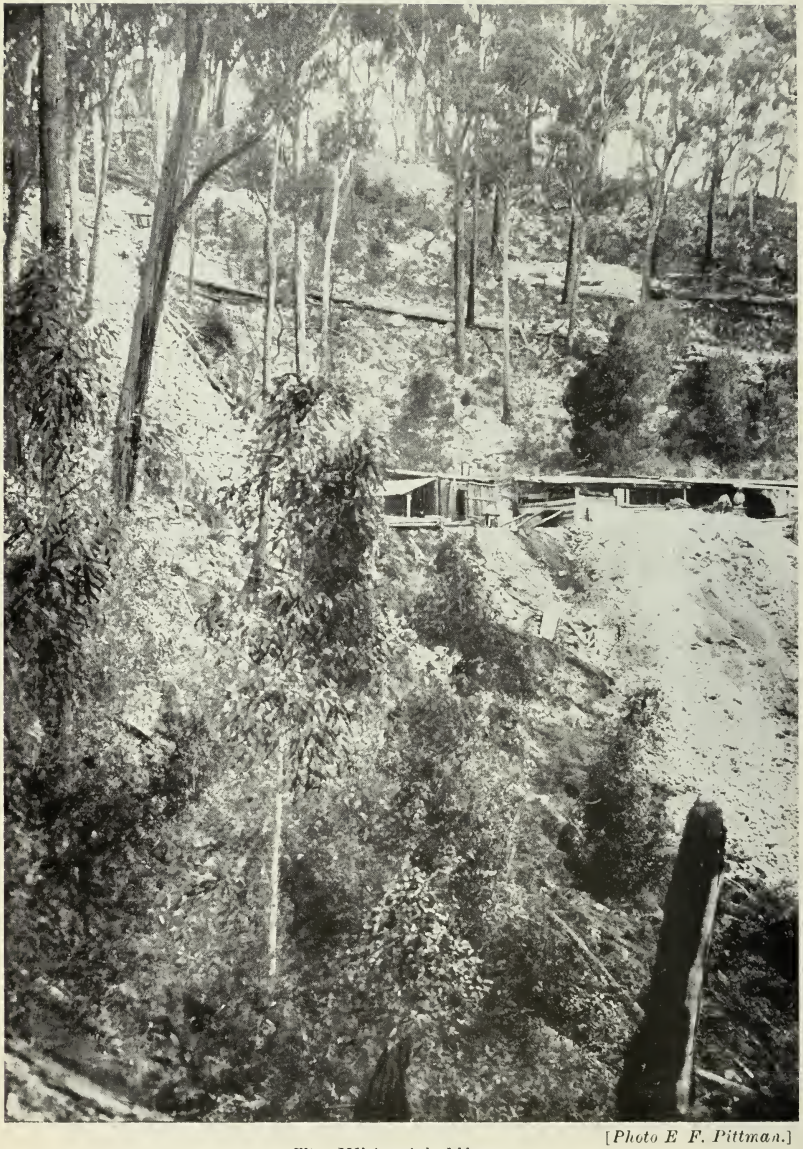
The pipe is somewhat irregular in size. In places it is from 5 to 6 feet in height and from 8 to 10 feet across.

A large dyke has intersected the pipe at a considerable depth below the surface, and the earlier workers of the deposit abandoned it because of the trouble caused by the dyke intrusion. Mr. W. Turbet and party picked up the pipe beyond the dyke and followed it along the contact. Aid from the Prospecting Vote was granted to prospect the pipe, and the deposit is being prospected under this grant. At the deepest point reached in March, 1916, the pipe appeared as though it might be about to leave the contact zone, inasmuch as the slate roof appeared to be rising while the pipe appeared to be descending. This, however, may be merely a local feature. In my opinion this pipe is worthy of further prospecting.

2. The Whipstick Mines, Ltd.—The accompanying sketch plans and sections illustrate the general occurrence of the pipes, but there is no pretension to accuracy in the plates and figures, as they have been compiled merely from measurements and directions supplied by Messrs. Schafer and Robertson during my tour of inspection. The figures, however, are approximately correct, and they illustrate the relation of the pipes to each other, as also to the granite and the altered sediments in the immediate vicinity.

The deposits outcropped on a steep hillside, and as they were followed below the surface the workings were connected by means of tunnels driven into the hillside for several hundreds of feet from which crosscuts were made to the mine workings. Vertical measurements in the mine are referred generally to the main, or No. 1 Tunnel, thus the bottom workings are spoken of as being 260 feet *below* the No. 1 Tunnel, while the No. 2, or main, pipe is

PLATE XXIII.



[*Photo E F. Pittman.*]

The Whipstick Mines.

said to disappear at a height of 100 feet *above* the No. 1 Tunnel. The No. 2 Tunnel is also spoken of as 100 feet above No. 1. This tunnel was driven for a distance exceeding 400 feet in order to test a well-defined quartz reef which has a long and well-marked outcrop. This reef is said to have been proved by the tunnel, but no deposit of commercial value was found therein, and the reef has not been tested further at this depth.

The bottom workings are in the main, or No. 2, pipe only, which is about 25 or 30 feet across in greatest measurement, the larger axis being almost north-east and south-west. The indications suggested by an examination of the workings about 25 feet higher up are that another pipe exists in the immediate vicinity.

At a height of 35 to 40 feet above the bottom a drive to the north-east has been put in a large garnet pipe. The deposit is large, and is about 25 feet in longer diameter, while its shorter axis or diameter has not been proved as yet. The garnet is massive, granular, and reddish. It contains irregularly-shaped patches of quartz, with native bismuth, sulphide of bismuth, telluride of bismuth, and molybdenite. This pipe was not met in the upper workings, and it has been proved only through a height of about 7 feet. It is almost in contact with the main, or No. 2, pipe.

The average content of bismuth and molybdenite in this great pipe is not known, but large rich bunches of ore are said to have been obtained therefrom, and according to Mr. Schafer, the returns were so promising that great hopes are entertained of a large supply of milling ore from this part of the mine. According to Mr. Schafer also, the bottom of the No. 2 pipe was systematically sampled for bismuth, and the result was about 1 per cent. of this mineral. This was done years ago, and the molybdenite content was neglected.

About 60 feet above the bottom workings, and 200 feet below the No. 1 tunnel, the main pipe in cross-section has maximum measurements of 25 and 15 feet, while the No. 3 pipe is about 7 feet in diameter. The workings are connected, and the longer axis of the pipes are almost collinear.

About 50 feet below the No. 1 tunnel, and about 200 feet above the bottom, the pipes exposed present an appearance much different from that at any of the lower levels. The main pipe has axial measurements of about 12 and 15 feet in cross-section, but the longer axis is not collinear with that of the associated pipes. No. 3 pipe appears to be leaving the main deposit more and more. No. 1 pipe, from 8 to 10 feet in diameter, is in contact with the main deposit. No. 1 pipe does not appear to have been proved much below this level, and it is probable that it has branched from the main pipe near this level. Two other pipes occur to the south of the axis along which Nos. 1, 2, and 3 are arranged. These are the No. 4 and the Pilot. The Pilot consists of brittle white quartz surrounded with a narrow zone of garnet, while the No. 4 is of altered granite surrounded in places with a narrow zone of white mica. The latter has an erratic course and has not been found above the No. 1 tunnel.

At the No. 1 tunnel level, the Nos. 1, 2, and 3 pipes have their longer cross axes arranged in a line or plane. The main, or No. 2, is large, but Nos. 1, 2 and 3 are relatively small. No. 3 is seen as diverging from No. 2. The No. 4 has disappeared, while the Pilot, with its enclosing zone of garnet, is still to the south of a line connecting the main axis of Nos. 1, 2, and 3.

The No. 2 tunnel is about 100 feet above No. 1 tunnel, and at a depth of a few feet below this level the longer axes of Nos. 1, 2, and 3 pipes are approximately collinear along a plane almost N.N.W. and E.N.E. No. 2 pipe is large. No. 3 here is distant 50 to 60 feet from the No. 2, while the Pilot has moved apparently round No. 2. It is here small and in contact with No. 2.

At and just above the No. 2 level a remarkable change is apparent in the arrangement and appearance of the pipes. The main, or No. 2, pipe has disappeared, except for the existence of a few patches of garnet and a narrow joint carrying much molybdenite. It is possible that this joint may lead in the direction of another deposit of bismuth and molybdenite at a higher level, but it must be admitted that the skilled and experienced prospectors of this field have been unable to trace the pipe in a vertical direction above the level. The Pilot also has been lost at this level. No. 1 is large and has diverged from the general direction of the No. 2, while No. 3 is also large and about 60 feet to the north-east of No. 2.

Prospecting operations at this level have led to the discovery of several large pipes leading upwards and connected only indirectly with either the No. 1, No. 2, or No. 3 pipes. Two of these lying to the south of the No. 2 are especially large, the No. 5, or the south stopes, being fully 30 feet in diameter. The Jump Up, or what may be called No. 6, inadvertently shown on the accompanying map as No. 2, on the plan as F, is about 20 and 25 feet in axial measurements in cross-section, and it is traversed by two, if not three, parallel dykes. One of the dykes is kaolinised, and appears to be a decomposed felsite, while a dyke alongside is hard and of felspar-porphyry. These dykes appear to have intersected the pipe, as the body is cut quite cleanly, the walls being sharp with a dig or "flucan."

Nos. 1 and 3 pipes outcrop on the hillside.

Treatment Plant.—The ore is crushed in a battery and passed over three Wilfley tables. The bismuth is collected as a marketable product over the end of the table, the molybdenite and the sands being elevated to a conical settling pit and passing thence to a 12-inch Mineral Separation unit. This plant is described elsewhere (p. 10) in the report.

As a guide to the recovery which may be expected to be made by the plant, the accompanying results of two trials by the Mineral Separation may be quoted from a return furnished by the Mineral Separation Company.

Both samples were crushed to 60 mesh.

Test I.	Weight.		Assay.				Recovery.
			MoS_2.	Bi.	Fe.	Insol.	MoS_2.
	lb.	%	%	%	%	%	%
Crude ore	1,906[a]	100	5·2	0·4	0·9	90·2	100·0
Concentrates	105	5·5	87·0	3·0	0·7	9·4	91·0
Residues	.....	88·6	0·2	...	...	...	3·4

[a] Eucalyptus, ¾ lb. a ton of ore.

The concentrates were refloated with a little sulphuric acid added. The middlings cut out from the concentrates contained approximately 3 per cent. molybdenite and 2 per cent. bismuth.

Test II.	Weight.		Assay.				Recovery.
			MoS_2.	Bi.	Fe.	Insol.	MoS_2.
	lb.	%	%	%	%	%	%
Crude ore	2,208	100·0	5·14	0·6	0·7	...	100·0
Concentrates	117	5·3	87·7	1·4	0·4	9·5	90·4
Residues	.....	93·3	0·3	...	...	0·4	8·4

Eucalyptus, ½ lb. a ton of ore.

The concentrate was refloated with a little sulphuric acid (½ lb. acid a ton of ore).

At the completion of the tests the concentrates were bulked and refloated producing a final concentrate assaying 90·5 per cent. molybdenite, and 1·3 per cent. bismuth. In this operation about 2 per cent. of the total molybdenite was left in the middling which would be re-treated in practice.

According to Mr. Schafer, the loss in the actual treatment up to date is about 0·4 unit molybdenite. This indicates the advisability of handpicking the ore to 4 per cent. molybdenite before treatment.

Future of the Mine.—In the earlier days of mining at Whipstick the molybdenite was rejected as an impurity in the bismuth ore. Moreover, owing to the primitive methods employed in the treatment of the bismuth ore, a considerable amount of the bismuth was not recovered also. This unrecovered material, in some measure, lies about the hillside near the mine workings.

During the years 1914 and 1915 a very large tonnage of this material was hand-picked and sent both to Sydney and elsewhere for treatment. A great amount, however, still exists on the hillsides and in the base of the small gully along which the surface mining workings have been carried out. Thus the plat at No. 1 Tunnel is triangular in plan, its apex pointing to the tunnel mouth and lying about 10 feet in front of same, and there ending abruptly against bed-rock in the steep gully bed. The distance from the apex to the centre of the base of the triangle is about 70 feet, and the length of the base is about 70 feet. This triangle base forms the edge of the plat, which slopes steeply thence to the gully base 45 feet vertically below. This heap contains from 1,750 to 2,000 tons of low grade ore necessitating hand-picking before its despatch to the mill, 1¼ miles away. According to Mr. H. Robertson, about one-half of the material composing these heaps is to be sent to the mill, but it is not possible, without experience, to estimate the average grade of this hand-picked material. Both on the plat, and below it, are large heaps totalling between 300 and 400 tons of low grade bismuth and molybdenite ore.

On the hillsides between No. 1 Tunnel mouth and the outcrop of No. 3 pipe about 200 feet vertically above other large deposits of low grade molybdenite lie scattered about, and the tonnage in these must be somewhat comparable with that in the large heap forming the plat at No. 1 Tunnel.

In the mine itself molybdenite ore occurs in the No. 3 pipe, about 40 feet below the surface. There is a large body of ore exposed in the main, or No. 2 pipe and the Garnet Pipe at the lowest levels worked as yet in the mine. Other ore patches of variable size occur in different parts of the mine such as the "Jump Up," the No. 3, and from a point below the No. 1 tunnel. From the two firstmentioned of these places the magnificent ore specimens were obtained which were sent to the Panama Exhibition and a fine sample of which is on view at the Departmental Museum at Miller's Point. In my opinion the Whipstick Mines are worthy of a vigorous policy of development and prospecting.

3. Young and Reid.—The leases held by these partners in 1915 consisted of M.L. 30 of 8 acres, and M.L. 33 of 10 acres, approximately.

The workings in these leases are numerous. Some are old while others are recent. They all occur in the granite near the old sedimentary roof. Most of them are shallow and show the usual favourable indications of manganese and mica gossans. Certain of the deposits appear to be arranged linearly, while others suggest a tendency to branch.

Wilson's Downfall Deposits.

1. *Flint's Molybdenite Vein.*—Described by Mr. E. C. Saint-Smith in 1909 as "3 chains south of the Maryland to Wilson's Downfall Road, on left bank of Tompkins' Gully, Parish Ruby, County Buller, 10 miles north-west of Wilson's Downfall.

Discovered by Thomas Flint about 1910. Only a few pieces of rock have been broken by fossickers. The molybdenite occurs as scattered small flakes in a coarse siliceous granite intruded by a small aplite vein with a strike of north 10 deg. east."

2. *Fordham's Molybdenite Vein.*—According to Mr. E. C. Saint-Smith the occurrence under consideration was noted in the "bed of Two Mile Creek, 2 miles south of Wilson's Downfall, Parish Corry, County Buller."

According to the same authority it was "discovered by Lewis Fordham about 1904, but no work was done. Strike N. 25 deg. E., and a dip apparently vertical. The molybdenite occurs very sparsely as fine blebs and scales in a narrow white quartz vein, 12 inches wide, traversing unaltered hard coarse biotite granite. Traced for a few feet in length. A similar vein, parallel to this one, occurs 10 feet away.

"This occurrence would seem to be worthless from a commercial point of view."

3. *Gunn's Authority.*—Portion 54, Parish Ruby, County Buller. Apparently molybdenite flakes in sandy granite. Information supplied by Mr. Warden Perry.

Hughes' Wolfram Lode.—Mr. J. E. Carne described this deposit as being "on the west side of the Wilson's Downfall-Stanthorpe Road, near Amosfield, 1 mile north-west of Wilson's Downfall, Parish Ruby, County Buller.

"Discovered about 1898, worked mainly by Rees Hughes in 1907–8 for about eight months, who opened it by a trench 40 feet long, and 9 feet at deepest.

"Examined in 1910 by E. C. Saint Smith, who described the wolfram as occurring in a bluish-white quartz vein, varying from 8 to 15 inches in width, which splits and reunites from point to point, small lenticular 'horses' of

* Tungsten Mining Industry. Mineral Resources, 15, 1911, p. 59.

aplite being enclosed by the quartz. Wolfram occurs in patches, principally in the central portion of the vein. It is associated with a little iron and copper pyrites, metallic bismuth, bismuth-carbonate, and flakes of molybdenite.

" Thin veins of quartz extend from the main vein into the aplite. The quartz is crystallised in part. The lode traverses aplite for the most part, but where it passes through coarse granite it is bordered by micaceous granite. The lode has been opened by small potholes for a length of about 600 feet.

" The molybdenite does not appear to occur in commercial quantity."

4. *Martin's Authority to Enter.*—Portions 72 and 73, Parish Ruby, County Buller. Molybdenite flakes in sandy granite. Information supplied by Mr. Warden Perry.

4a. Maryland. *See* Waterson's (John) Claim.

5. *Staine's Lease.*—P.M.L. 1, of 5 acres, within Portion 72, and an Authority to Enter of about 5 acres, adjacent to P.M.L. 1 on the west, within Portion 68, Parish Ruby, County Buller, at Maryland, and about 8 miles north-north-east of Wilson's Downfall.

Molybdenite occurs as fairly large flakes and crystals in a coarse siliceous granite near its junction with a granite of very siliceous nature. Upon casual inspection the molybdenite appears to be scattered at random throughout an unaltered granite, but upon closer inspection it may be seen to be associated, in places, with very small flakes of secondary mica along tiny joints, as also at the intersection of these joints. Quartz is also associated with the molybdenite. Alongside certain of these joints the granite is discoloured for widths varying from 1 to 10 inches, and this discolouration appears to be due to an oxidation of iron which had been introduced, probably as iron pyrites, into the granite along the joints which favoured the passage of the molybdenite and silica vapours. Fig. 1 illustrates a detail of this occurrence seen on the outcrop alongside the open cut. It suggests an early stage in the formation of a " granite " pipe (see p. 28).

The workings occur in the northern portion of P.M.L. 1, and they consist of an open cut about 40 feet in length and 15 feet deep at one point. The prospects are not encouraging, from a commercial point of view, as there appears to be very little hope of expecting the tiny intersecting joints to form a pipe lower down.

6. *Stalling's Lease.*—M.L. 2, of 8 acres, on Crown Lease, Parish Wylie, County Buller, alongside main road from Stanthorpe to Wilson's Downfall, and about 1 mile from Wilson's Downfall. According to the statement of of the prospector, Mr. H. J. Stalling, molybdenite in small veins of quartz has been found in the lease traversing a sandy and cavernous granite of fine texture near its intrusive contact with a coarse hornblende granite. Wolfram occurs also in the lease, but is not associated directly with the molybdenite. Mr. Stalling stated that one shaft was about 40 feet deep in September, 1915, and that other prospecting work had been done also. The veins appear to be narrow, six in number within a belt of country rock about 50 yards in width. The strike of the deposits is said to be parallel to the longer sides of the lease, that is about north-east and south-west, and the veins are said to persist throughout the length of the lease. The molybdenite is said to occur as large flakes in brittle, white, and cavernous quartz.

7. *Sugarloaf Mountain.*—Parish Ruby, County Buller, on the New South Wales-Queensland border, about 12 miles west of Wilson's Downfall village.

The mountain is rugged and rises about 3,700 feet above sea level, and about 600 feet above the Wilson's Downfall Plateau.

Mr. E. C. Saint-Smith reports* that "the summit of the Sugarloaf Mountain is composed of a coarse-grained granite . . . . . Several veins of greisen occur through the rock mass, especially at the head of Herding Yard Creek and its tributaries on the Queensland border. These veins as a rule carry tinstone, wolfram, and a little molybdenite, with occasional coatings of iron and copper pyrites along joint faces."

Sugarloaf Claim.—M.L. 50, about 20 acres approximately, Parish Ruby, County Buller, at Sugar Loaf Mountain.

In the north-eastern portion of the lease a great number of loose fragments of impure quartz were seen. These contain flakes of molybdenite and appear to have been shed from a vein.

In the western portion of the lease a small quartz vein outcrops with a strike approximately north 40 degrees east, and a dip almost vertical towards the south-east. The vein has been proved for 70 yards at least within the lease, and it has been traced for a considerable distance within the State of Queensland to the west. The vein traverses granite of fine texture and very siliceous nature near its intrusive contact with a basic granite containing much hornblende.

The minerals found in the vein include wolfram and scattered flakes of molybdenite. The deposit was prospected many years ago for wolfram by means of shallow shafts and open cuts, the depths of which vary from 5 to 25 feet approximately. In one of these open cuts, now partly filled with waste, and about 15 feet in depth at the present time, the vein may be seen to be split into two, each about 4 inches wide near the surface, and forming one vein about 8 or 9 inches in width at a depth of 12 or 15 feet.

The wolfram in the vein is in the form of plates, and is of good quality. The molybdenite occurs as scattered flakes of small size in the silicified granite alongside the quartz vein. Fig. 28 illustrates the approximate position of the vein in the lease.

Mr. R. F. H. Ormiston has a lease of the area at the present time, and he states his intention of working the quartz vein for both wolfram and molybdenite. The prospects for wolfram are certainly encouraging.

This vein may be the same as that described as Stalling's Lode, by Mr. J. E. Carne, which was discovered by G. and F. Stalling in 1892, but not worked until 1907, and in which wolfram, with a little molybdenite, was reported to occur.

9. *Waterson's (John) Claim,* Maryland.—This has been worked by means of a Mineral Prospecting Area of 40 acres, near Portions 78 and 79, on Crown land, and held as a special lease by W. Waterson, in Parish Ruby, County Buller, at Maryland, about 8 miles to the north-north-west of Wilson's Downfall.

The occurrence is of the nature of a granite and pegmatite "pipe" about 9 or 10 feet in diameter, within a coarse siliceous granite. The pegmatitic granite composing the "pipe" is variable in appearance, and may consist of:—

(*a*) Large long crystals of orthoclase felspar in a glassy paste of bluish and translucent quartz.

(*b*) Irregular patches of an intimate mixture of quartz and felspar grains in a paste of translucent bluish and glassy quartz.

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* J. E. Carne. Tin Mining Industry. Mineral Resources, 14, 1911, p. 84.
* The Tungsten Mining Industry. Mineral Resources, No. 15, 1911, p. 67.

The pipe, so far as proved, is vertical, but the greatest depth reached appears to be only about 20 feet. The shaft was half filled with muddy water during my visit in September, 1915, thus the lower portion of the workings could not be examined at that time. From the nature of the specimens lying about the surface, and the general appearance of the pipe near the surface, however, it would appear that the deposit is worthy of further prospecting. Rich specimens have been obtained in the pegmatitic material usually as large, but thin flakes.

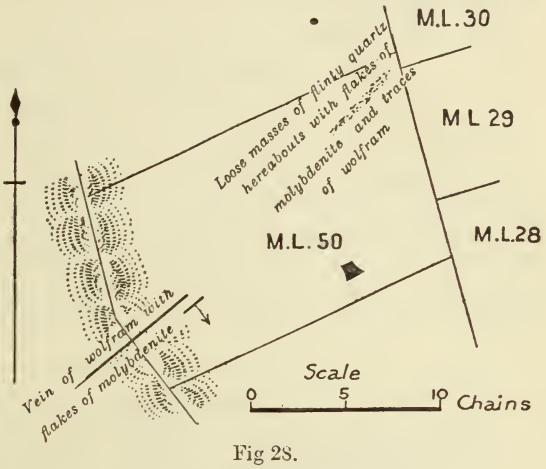

M.L.30
M L 29
M.L.28
M.L. 50
Loose masses of flinty quartz hereabouts with flakes of molybdenite and traces of wolfram
Vein of wolfram with flakes of molybdenite
Scale
0 5 10 Chains

Fig 28.

Parish of Ruby, County of Buller.

Occurrence of Molybdenite with Wolfram at Sugarloaf Mountain, Wilson's Downfall.

10. *Waterson's (J. F.) Claim.*—Two Authorities to Enter on W. Stonebridge's C.P., Portions 58 and 59, Parish Ruby, County Buller, about 3¼ miles north of Amosfield.

According to Mr. J. F. Waterson, molybdenite occurs here with wolfram in a small quartz reef in granite. The strike of the reef is approximately north-east and south-west.

10. In a cutting along main road from Wilson's Downfall to Stanthorpe. ¾ mile from first-named township.—Occurrence :—As a great number of scales and small flakes of molybdenite *scattered throughout* a miarolitic eurite dyke, The dyke is about 100 yards wide, and has its mica (biotite) in irregularly scattered plates (similar to mica in graphic granite). The association of the molybdenite with the peculiar miaroles shows it to be part of the intruding body which has cooled out in isolated patches, the hydration not being pronounced enough to allow of the concentration of the mineral in quartz veins.

The "sandstone" granite containing this molybdenite deposit intrudes the coarse porphyritic granite of Wilson's Downfall. This latter is a unique rock type, and contains innumerable patches of tin greisen, also wolfram. The later "sandstone" granite occurs as bosses from 2 to 3 miles in diameter, with networks of dykes radiating therefrom.

Wolfram Blow. *See* Kingsgate.

Woomargama Station. *See* Holbrook (in Appendix).

Woy Woy Creek. *See* Nambucca.

Wunglebung. *See* Rocky River.

Wymah.

Yarrahappini Mountain. *See* Nambucca.

YARRAS.

"About 4 miles westerly from the copper lode, on the Forbes River, a reef carrying fair bunches of molybdenite on the surface has been opened recently, but as only a limited amount of work has been done no opinion can be formed of the prospects."

[Extract from *Prospector's Guide, N.S. Wales*, p. 82.]

YARROW CREEK. *See* Kingsgate.

YATES (W. H.). *See* Kingsgate.

YETHOLME DISTRICT.

The examination of the Yetholme molybdenite deposits was commenced in June, 1915, by Mr. J. E. Carne, Government Geologist, and the Writer, several days being spent on the Mount Tennyson or northern portion of the field. In November the Writer spent several days at these deposits and the neighbouring ones of Gemalla and Tarana, while in January, 1916, he revisited the area for a couple of days with Professor H. E. Gregory, of Yale

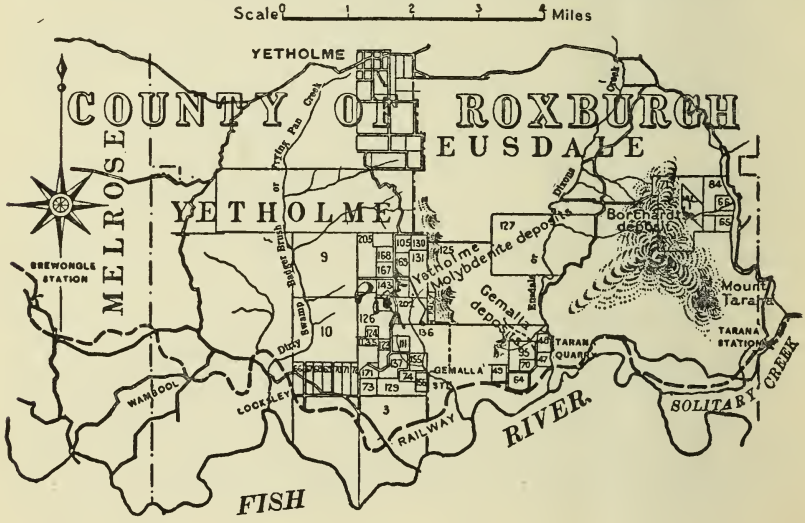


Fig. 29.

Plan showing the position of the Yetholme and Eusdale Molybdenite deposits.

University, New Haven, U.S.A. A preliminary report was prepared jointly by Messrs. Carne and Andrews. This earlier note has been printed in the Government Geologist's report for 1915.*

Situation and communication.—The more important of the molybdenite deposits occur in the eastern portion of Parish Yetholme (Fig. 29), and the less known Gemalla deposits occur a few miles to the east, that is, in the western portion of Parish Eusdale, County Roxburgh. With these may be included the Tarana deposits lying a couple of miles farther east, also in Parish Eusdale. Both the Yetholme deposits proper, or Mount Tennyson,

* Annual Report, 1915, p. 176–177.

PLATE XXIV.

[*Photo J. H. Fawcett*]

(*a*) Mount Tennyson and the Macquarie Valley. The valley is about 1,400 feet deep. The knob shown just beyond Garrard's house is a garnet outcrop.

[*Photo J. H. Fawcett*]

(*b*) Mount Tennyson from Wambool. The garnet rock extends from 0 to 0, and still further to the east.

and the Gemalla deposits lie near the Great Western Railway line, the former about 2 miles northerly of Locksley, the latter 2 miles northerly of Gemalla railway station. The Tarana deposits lie about 3 miles northerly from Tarana railway station. Tarana, Gemalla, and Locksley stations are distant from Sydney by rail, 120, 125, and 129 miles, respectively, and are respectively about 2,563, 2,538, and 2,500 feet above sea level, while the highest points of the molybdenite workings at Tarana, Gemalla, and Yetholme respectively are about 3,100, 3,800, and 3,800 feet above sea-level, respectively.

No direct road connects the Yetholme and Gemalla deposits with the railway stations, and in the case of the Mount Tennyson or Yetholme deposits proper, all passenger and goods traffic at present is with Wambool railway station, 131 miles from Sydney, and 2,600 feet above sea-level. A steep road with good surface and about 8 miles in length connects Wambool with Yetholme, 3,600 feet above sea-level, approximately, thence communication is secured with the Mount Tennyson deposits by bush road about 5 miles in length. A considerable amount of money would be needed to secure a good connection by road with these deposits either from Yetholme or Locksley, inasmuch as most of the deposits outcrop on the sides of deep and steep ravines. (Pl. XXIV.)

Similar remarks apply to the case of any proposed connection by road with the higher deposits at Gemalla.

Geography.—The district is drained by the Fish River, one of the two main tributaries of the important Macquarie River. The Fish River is distant only 2 or 3 miles in a straight line from the Yetholme deposits, but whereas the stream is only about 2,450 feet above sea-level at Tarana, the upper deposits of Mount Tennyson, as near Garrard's House, are about 3,800 feet above that level. The appearance of the wide and deep Macquarie valley, from Mount Tennyson itself, is such as to suggest that the Macquarie River carved its own valley out of the plateau. This was not the result of a simple operation but of one which has been repeated or renewed at various times, because traces of old valley floors are to be seen at levels much higher than the present river level. Thus there appears to be a general north-westerly pitch to the main plateau surface of the region. Yetholme, Blayney, and Orange lie on this dissected level while high residuals of former land masses rise above this general surface. Examples of such residuals are the Tarana, Yetholme, Sunny Corner, and other Trigonometrical Stations, as also large sub-horizontal masses as Sunny Corner hills themselves. Through this general plateau surface the Macquarie appears to have cut a shallow but very broad valley, many miles indeed in width. Remnants of this floor are to be seen around Brewongle, Wambool, Mount Pleasant, and other places, and lying from 2,600 to 2,800 feet above sea-level. Below this broken surface the river has excavated other broad and shallow valley-in-valley structures, the whole appearance being strongly suggestive of a former surface of low relief, which had been raised in the past, thus enabling the Macquarie streams to excavate a broad and shallow valley in the low plateau. During periods still later the land rose again giving increased cutting power to the streams; thus the main broad valley now has the appearance of valley-in-valley structures. The valley proper of the Macquarie has been excavated within dense granite structures, nevertheless, these are weak as compared with the associated Devonian, Silurian, and other Palæozoic structures of Sunny Corner, Yetholme, Tarana, Orange, and Oberon. Thus, while the main Macquarie has worn the granite of the Bathurst district down to broad

undulating forms the side streams have excavated gorges only in the dense Palæozoic structures of the higher plateaus. So marked is this difference in strength between granite and altered sediments, associated with the granite, that near Tarana the river flows within the granite, and is overlooked by sediments forming dissected escarpments rising from 1,000 to 1,200 feet above the river, and having an alignment such as to suggest a fault-origin for the valley at this point.

This alignment of spur points at one time led the Writer to a belief in the origin of the Macquarie valley by the action of faulting,* but an examination of the Cargo Gold Field and the Yetholme molybdenite deposits has led him to the belief in the origin of the great valley by the action of running water.

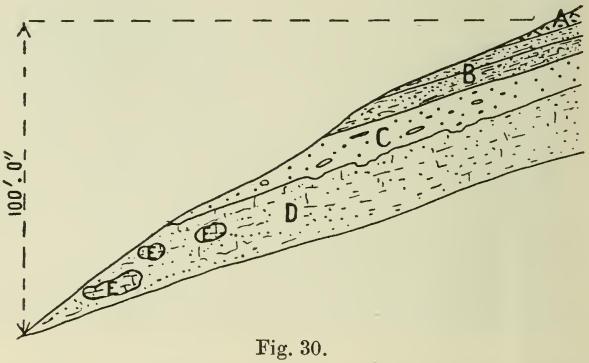


Fig. 30.

Sketch section across altered sediments near north-west corner P.M.L. 5, Parish of Yetholme, County of Roxburgh.

A—Quartz porphyry.
B—Silicified porphyry (?), containing hornblende, garnet aggregates and wollastonite.
C—Granular garnet rock containing amphibolite, silicified sediments, small quartz aggregates and molybdenite. Maximum thickness from 20 to 35 feet.
D—Mass of limestone with claystone altered to granular marble, wollastonite and garnet with silicified claystones.
E—Large masses of altered marble.

Geology.—The geology of the Yetholme field is highly interesting, and is well worthy of detailed study by a research student. The accompanying notes are merely of reconnaissance nature, and are based upon field notes made during a couple of visits extending over about eight days all told. The accompanying map, sections, plates, and sketch figures will help to make the descriptions clear.

General Geology.—The Yetholme and Gemalla molybdenite deposits fall under the head of contact deposits. A large mass or bathylith of granite has intruded the older Palæozoic sediments of the Bathurst district. The granite characteristically forms the lower portions of the landscape, while the altered and folded sediments associated with the granite, and intruded by the same, stand out as high and deeply-dissected surfaces. This is only true in the main, for the bathylith is of the composite type, being of basic nature for the greater part, but containing large masses of very siliceous granite in the eastern and southern portions. These siliceous types stand up as high residuals of the lower land surface cut in the basic granites or they

* The Geographical Unity of Eastern Australia in Tertiary and Post-Tertiary Time. Procs. Roy. Soc. N.S. Wales, vol. XLIV, 1910.

form portion of the higher plateaus as at Tarana Mountain or Yetholme village. The bathylith extends east and west from a point near Rydal to a point about 15 miles west of Bathurst, a distance exceeding 40 miles, while it has a great development both north and south of Bathurst. The late Mr. W. J. Clunies Ross suggested that future workers might establish a laccolithic origin for the bathylith.* The more northern, central, and western portions of the mass are of basic nature and good crops of wheat and other produce have been obtained from this type for the past sixty years. It is the rock mass underlying the " Bathurst Plains."

In the neighbourhood of Yetholme and Gemalla the siliceous granites appear to have intruded the basic granite near its intrusive contact with the older Palæozoic sediments. To the immediate north of Yetholme the siliceous granite is aplitic in appearance in places, in others porphyritic, fine in texture, and miarolitic. In these types scattered flakes of molybdenite occur as an accessory constituent. Still farther north the granite is coarse and more basic and contains small quartz veins with flakes of molybdenite, as in Donaldson's paddock. Under Mount Tennyson, or the Yetholme molybdenite field proper, the granite is coarse and siliceous, but between it and the intruded sediments, in patches, there exists a marginal development of considerable width of a granite of varying texture and composition. In places it has the appearance of a siliceous pegmatite; in others it appears as an aplite, while in other places it merges into a granite of fine texture containing small crystals of ferro-magnesian minerals.

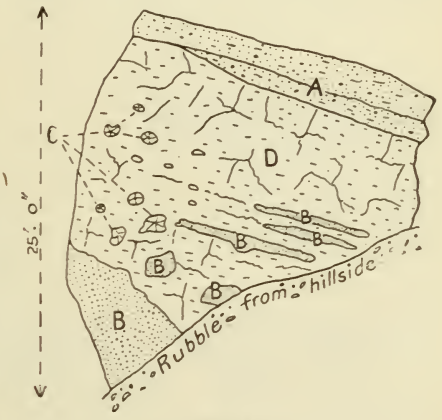


Fig. 31.

Sketch section across garnet rock near south-western corner of P.M.L. 5, Parish of Yetholme, County of Roxburgh.

A—Granular garnet with blebs and patches of glassy quartz, containing flakes of molybdenite.
B—Large blocks of sediment altered by introduction of silica, lime, and iron.
C—Large and small patches of radiating wollastonite, generally spheroidal.
D—Mass of segregations of wollastonite with cement of granular garnet.

The contact zone is wide, long, and narrow, extending for several miles along the granite margin, and extending about 1 mile into the sedimentary rocks at the most. The zone of alteration may reach about 200 feet in thickness as a maximum, while that portion of the alteration zone which contains the molybdenite has not been proved to exceed 30 feet in thickness, excepting in one spot.

The sediments intruded are older Palæozoic limestones, claystones, sandstones with quartz porphyry masses apparently as interbedded flows. The vegetation of the quartz-porphyry is peculiar, consisting of stunted growths of *Eucalyptus Cambagei* (Bundy), *E. dives* (Peppermint), *E. maculosa* (White

* Personal communication in 1894.

Gum), *Brachylome daphnoides*, and dense growths of *Stypandra glauca*, and *Poa cæspitosa*. The limestones occur as small lenses, and have been changed to sugary marble. The beds associated with the limestones are of fine texture, and they occur in very numerous and very thin beds. They have all been intensely silicified, and in places appear as quartzite, or flinty claystone. They may be altered claystone beds or volcanic ash. There is probably a considerable calcareous content in their composition. They are distinguished particularly by a development of luxuriant growths of *Casuarina stricta*, or long-leaved oak.

The molybdenite occurs mainly in a garnet zone, and this, in the northern portion of the field, appears to overlie the so-called claystone, or volcanic ash, beds and the altered limestone lenses while it is in turn overlain by the quartz-porphyry and ash beds. On the southern portion, however, of Mount Tennyson in the vicinity of Kirk and Wade's blocks, the garnet zone is both overlain and underlain by the so-called claystone beds, the limestone being

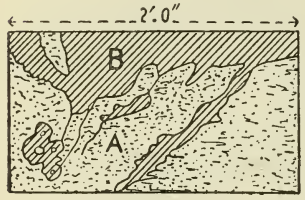


Fig. 32.

Detail of alteration in P.M.L. 10, Parish of Yetholme, County of Roxburgh.

A—Silicified sediments.

B—Alteration of sediments to siliceous material, containing garnet, hornblende, and other minerals.

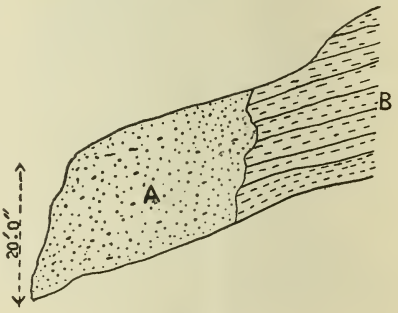


Fig. 33.

Sketch section of rock structure in P.M.L. 15, Parish of Yetholme.

A—Granular mass of garnet, with quartz and traces of molybdenite.

B—Bedded claystones (?), altered to siliceous masses, with wollastonite and garnet segregations and amphibolite.

absent, and the quartz-porphyry and ash beds being above the zone of alteration. In Parish Gemalla the garnet rock is pronounced but relatively thin, the zone of alteration is not thick, and the overlying and underlying beds are different from those of Mount Tennyson. At Borchardt's claim, on Tarana Mountain, the siliceous granite is associated with a sill about 25 feet thick of fine-grained granite (Fig. 42). A zone of alteration, somewhat similar to that at Yetholme occurs on each side of the sill. In this case the underlying rocks appear to have been claystone altered to quartzites, and the overlying rocks appear to be fine volcanic ash or sandstone. No limestone was obeerved *in situ*.

The garnet rock, therefore, does not appear to have been developed between any two particular layers of sediment or rock, except locally.

The garnet zone may occupy the central portion of the belt of alteration; or the alteration may occur either above or below the garnet layer in the main. These points are illustrated in the accompanying coloured plan and sections.

This garnet zone, again, is of variable width. In some portions of P.M.L. 15, it has been seen about 25 feet in thickness, whereas in others it has been seen

EPOSITS

IE)

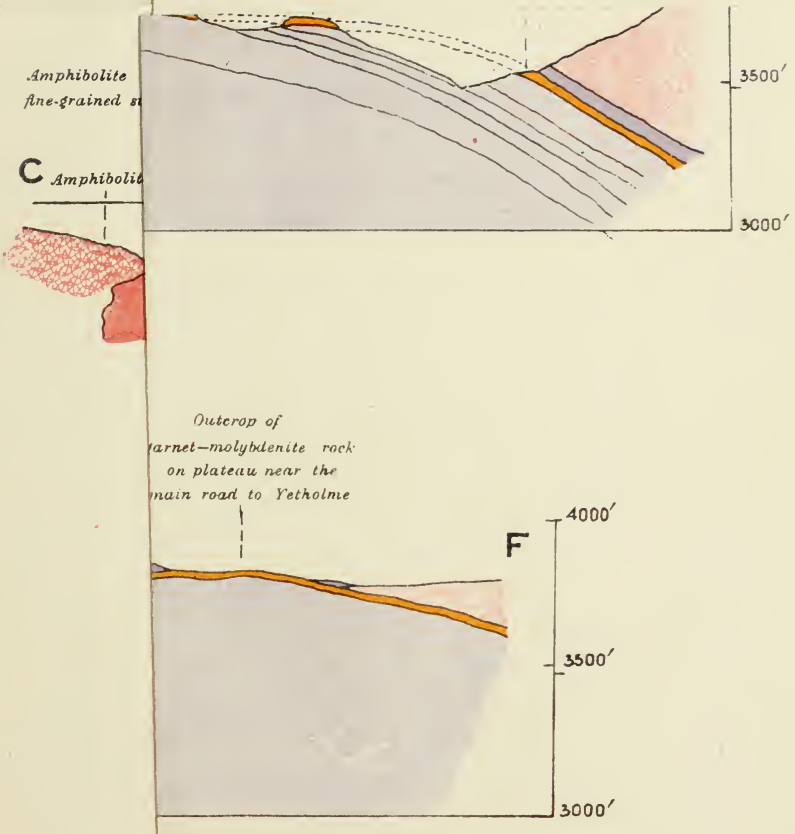
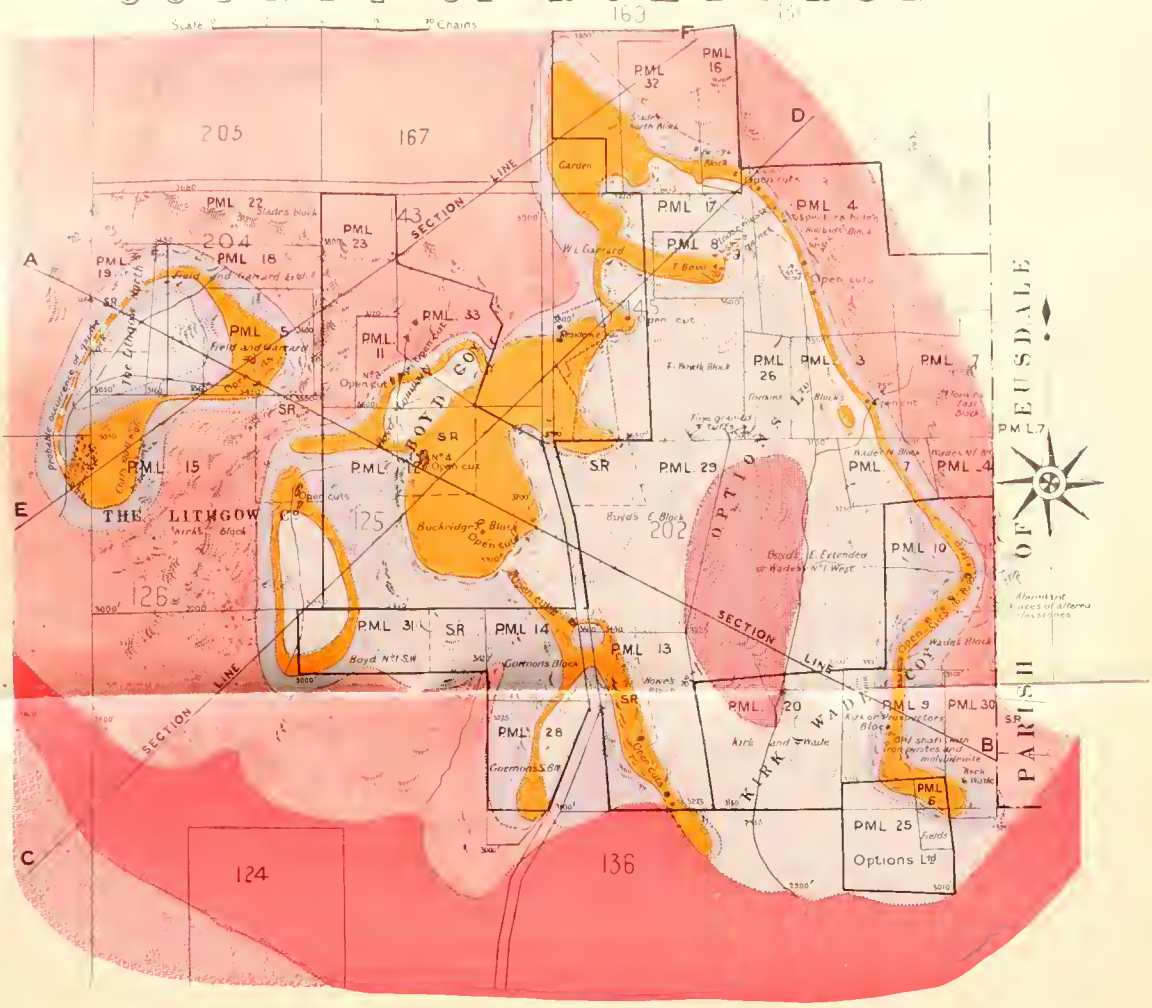


PHOTO-LITHOGRAPHED BY W.A. GULLICK, GOVT. PRINTER, N.S.W.

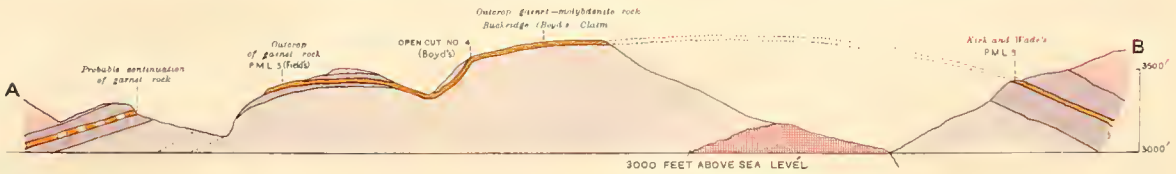
SKETCH GEOLOGICAL PLAN OF THE MOLYBDENITE DEPOSITS
AT
MOUNT TENNYSON (YETHOLME)
PARISH OF YETHOLME
COUNTY OF ROXBURGH



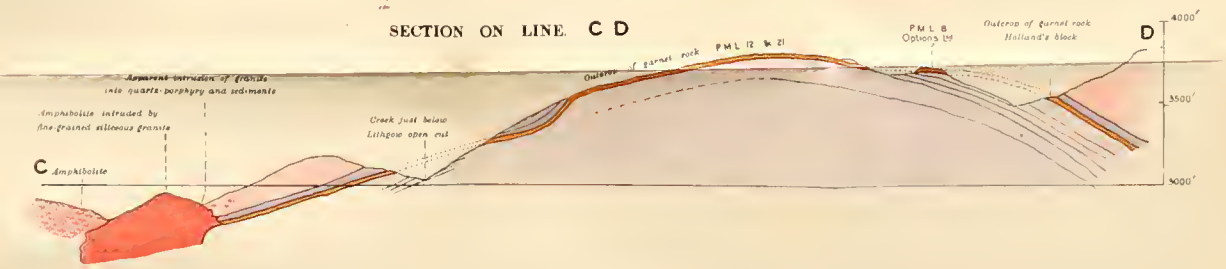
SKETCH SECTIONS

Horizontal Scale 0 5 10 Chains Vertical Scale 0 330 660 Feet 0 5 10 Chains

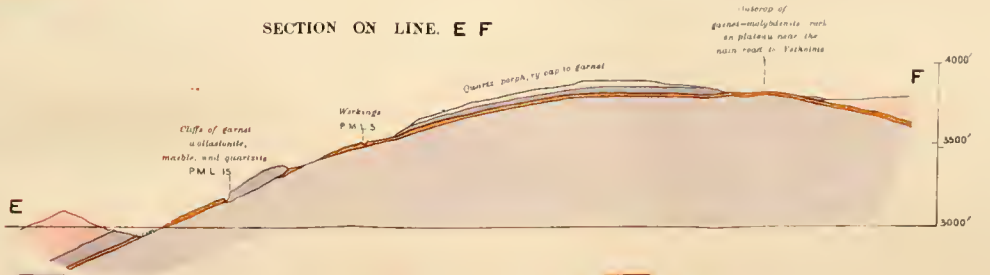
SECTION ON LINE A B



SECTION ON LINE C D


PML 8 Options Ltd
Outcrop of garnet rock Holland's block
Outcrop of garnet rock PML 12 & 21
Apparent intrusion of granite into quartz-porphyry and sediments
Amphibolite intruded by fine-grained siliceous granite
Creek just below Lithgow open cut
C Amphibolite
D
4000'
3500'
3000'

SECTION ON LINE E F



Claystones quartz porphyry tuffs and limestones altered to garnet, wollastonite and quartzite with epidote Silurian(?)
Quartz porphyry with sandstone claystone and tuffs (?)
Garnet rock containing epidote, amphibolite quartz and molybdenite
Siliceous granite intrusion, pegmatite near margin
Amphibolite
Diorite
Paleozoic sediments

PHOTO-LITHOGRAPHED BY H. BULLOCK, GOVT PRINTER, N.S.W.

no thicker than 2 feet; and again in P.M.L. 15 it has been observed to die away altogether over small areas (Figs. 33, 34 and Map). The garnet belt contains the molybdenite, amphibole, epidote, calcite, and quartz in various forms, generally as small lenses, eyes, streaks, tiny veins and small patches of irregular shape. In the region of the granite and the limestone patches the zones of alteration, or zones of transition between the garnet-molybdenite layer and the unaltered sediments are of considerable thickness, but at considerable distances from the granite, limestone being absent also, the zone of alteration or transition is not thick.

This zone of alteration has an interesting mineral composition. In the northern end of the field, as in Kirk's and in Field and Garrard's blocks, limestone patches outcrop within the zone, and these may be seen to be traversed by networks and knots of granular garnet of a brown to honey colour. (Fig. 36.) Large spheroidal masses of wollastonite also occur in the altered limestone (Figs. 34, 37, 38). Surrounding these limestone masses beneath the garnet layer are considerable thicknesses of altered sediments of fine texture. These, for very many feet vertically, have been intensely silicified, while in many places they have been altered in other directions. This more intense alteration is of a patchy nature, taking the form of huge pockets beneath the garnet zone (Fig. 39). In these pockets the [Figs. 31, 34, 38, 44, and 45] alteration products consist of spheroids of cherty or flinty material, veins and patches of impure quartz, spheroids of granular marble, spheroids large and small, of wollastonite, and strings, kernels, knots and patches of granular garnet. Patches of calcite with crystallised garnet are also common, one rhombohedron of the latter mineral exceeding 2 inches in diameter. Above the garnet zone in the northern portion of the Mount Tennyson area, the alteration belt is banded, the bands being parallel both to the general plane of the garnet-molybdenitee zon and to the dip of the beds generally (Figs. 35 and 36).

These altered and overlying rocks are mainly quartz-porphyry types, and the parallel zones or belts traceable in them consist in the main of wollastonite masses. These are mainly spheroidal or ellipsoidal in shape, and they may, or may not, possess kernels of sugary or granular marble. Figures 34, 37, and 45, illustrating this feature, are sketch sections of such forms from measurements by Professor H. E. Gregory and the Writer. These wollastonite masses with marble kernels may occur either above or below the garnet-molybdenite zone, and they cannot be shown to have been derived directly from the limestones of the vicinity. In the southern portion of the field, as in Kirk and Wade's blocks, and at Borchardt's lease on Mount Tarana, there are numerous spheroidal or ellipsoidal masses of wollastonite, some with kernels of marble (Figs. 37 and 45), which occur in large pockets of alteration (Figs. 36 and 39) in sediments which appear to be altered claystone or volcanic ash-beds of very fine texture.

It would appear, as a result of this very incomplete examination, that a composite bathylith had intruded the older Palæozoic sediments of the Bathurst district in post-Devonian and pre-Permo-Carboniferous time, that the portions intruded first were basic granites and allied types, and that these were intruded in turn in the Yetholme area by very siliceous granitic rocks of variable texture and mineral composition, and that these siliceous types were arranged marginally to the great mass of the granite intrusion proper. Vapours containing molybdenum, sulphur, iron, abundant silica, as well as other elements, appear to have been expelled from these siliceous

granite types into certain zones of relative weakness in the associated and intruded palæozoic sediments. The zones, along which the vapours could advance with relative ease, were the bedding planes of the sediments and and lavas, the forms assumed by the action of the vapours are very similar to those of sills, in that they conform to the bedding planes in the main, but transgress them in places, thus passing, in places, from one set of bedding planes to another.

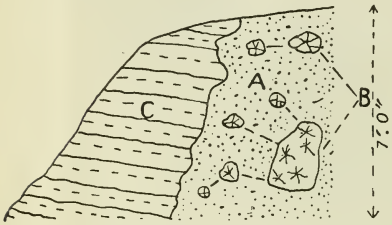


Fig 34.

Sketch section of rock exposure, P.M.L. 10, Parish of Yetholme.

A—Garnet paste, containing small and large aggregates of wollastonite.

B—Spheroids of wollastonite.

C—Silicified sediments encroached upon by formation of granular garnet rock.

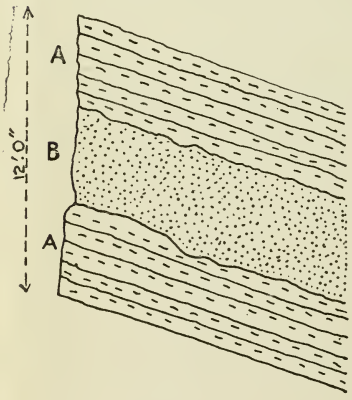


Fig. 35.

Sketch section near south-west corner P.M.L. 15, Parish of Yetholme.

A—Fine-grained sediments altered to greenish mass of wollastonite, silica, hornblende and garnet.

B—Compact brown mass of granular garnet, with small patches of quartz and traces of molybdenite.

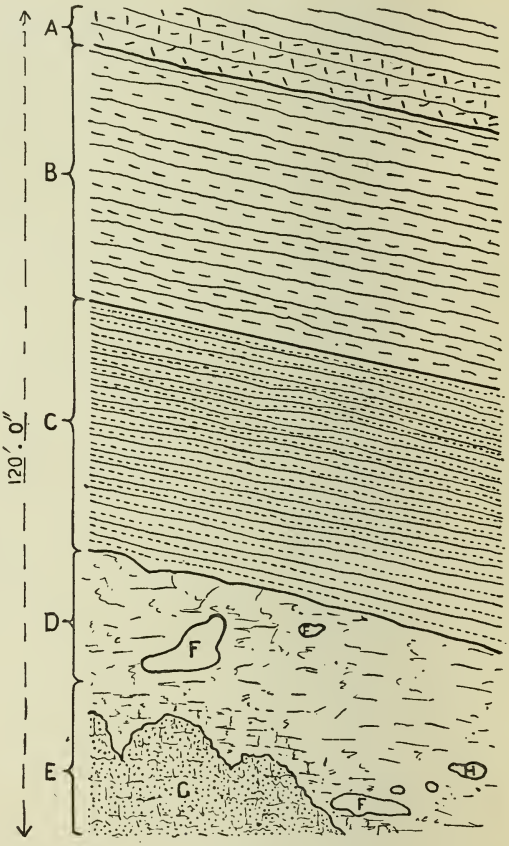


Fig. 36.

Sketch section based upon observations taken on cliffs in P.M.L. 15, Parish of Yetholme.

A—Quartz porphyry.

B—Silicified porphyry, containing amphibolite and wollastonite, with some garnet (the so-called diorite of the miners).

C—Silicified rock, containing a low percentage of molybdenite.

D—Mass of altered claystones and limestone.

E—Altered limestone bed.

F—Silicified fragment (15 feet long) of claystone.

G—Granular marble invaded by strings, and aggregates of garnet.

H—Large aggregates of wollastonite in paste of garnet.

The beds affected by the vapours were limestone, quartz-porphyry, claystone, sandstone, volcanic ash, and possibly other types. From the limestones and associated sediments containing lime the vapours appear to have caused some segregation of lime, as marble, to take place both in the limestones themselves and in the claystones and quartz-porphyry. With the continuous discharge of silica in the granitic vapours the limestone and the calcareous segregations became changed to silicates of lime as wollastonite, while with an interaction also between the iron and alumina content in the sediments,

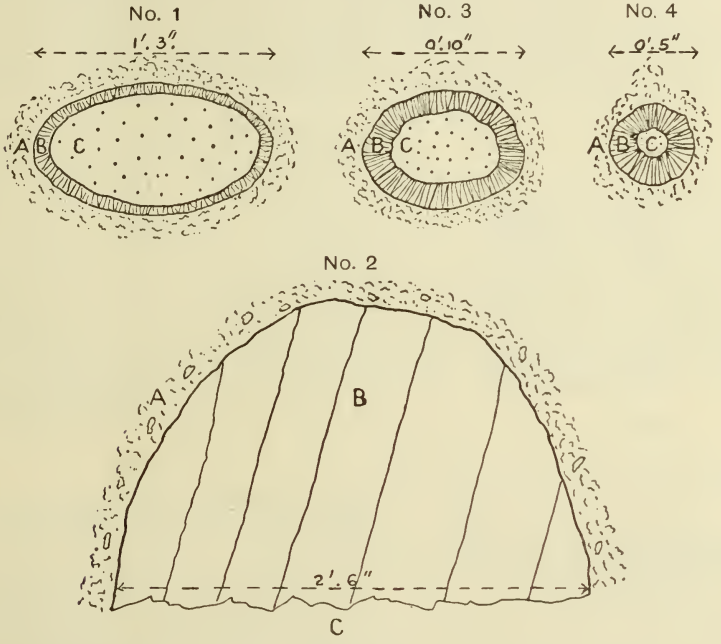


Fig. 37.

Sketch of inclusions of garnet rock at Yetholme and Tarana. Based on measurements by Dr. H. E. Gregory and E. C. Andrews.

Nos. 1, 3, and 4.

A—Garnet, wollastonite, epidote, &c.
B—Zone of wollastonite.
C—Marble.

No. 2.

A—Garnet, claystone, epidote, &c.
B—Banded marble.
C—Talus in creek bed.

these calcareous segregations became changed in great measure also to amphibole, epidote, and garnet. The vapours from the granites were not able, of themselves, to change completely the lenticular masses of limestone which they had invaded, and they simply formed within them either pockets of massive garnet or networks of the same material. Wollastonite masses were indeed formed within the limestone lenses, but both wollastonite and hornblende were developed more characteristically in rocks, which were either of claystone and quartz-porphyry, and even had they been derived

from the limestones originally, they must have travelled long distances thence so as to form the calcareous secretions and minerals at Tarana and Gemalla. It would, indeed, appear legitimate to infer that much of the lime was contained originally in the sediments other than limestone proper. The most complete replacement appears to have taken place in the space occupied now by the ore deposit itself, which is composed mainly of garnet, amphibole, quartz, calcite, and molybdenite, with huge inclusions of what appear to be sediments, or porphyry, of fine texture in all stages of digestion (Figs. 31, 32, 34 and 38). The prevailing tendency in the more central plane of circulation, now the ore deposit, was to form pure silica, and in proportion to the development of this mineral in streaks and small lenses or patches, so was there a tendency for the formation of molybdenite flakes in the altered rocks.

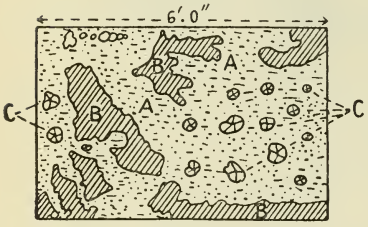


Fig. 38.

P.M.L. 10, Parish of Yetholme.

Altered rock underlying garnet rock.

A—Paste of granular siliceous rock containing aggregate of garnet and wollastonite.

B—Large fragments of silicified sediments.

C—Spheroidal aggregates of wollastonite.

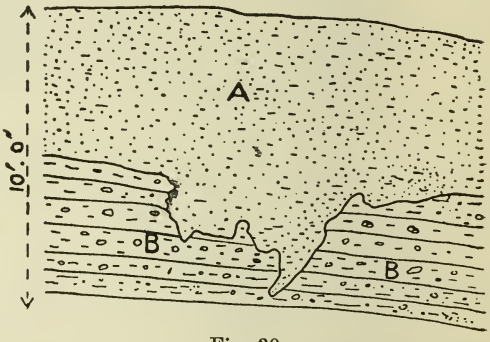


Fig. 39.

Sketch section across rock structures near north-west corner of Surface Right P.M.L. 5, Parish of Yetholme.

A—Compact granular garnet rock, with small irregular patches of glassy quartz and flakes of molybdenite.

B—Beds of altered sediments, containing spheroids of wollastonite, and segregations of granular garnet. Rock of this nature is generally honeycombed on outcrops owing to removal of the wollastonite.

This mineral occurs both as small flakes and as paint molybdenite in the garnet-rock, being of rare occurrence in the wollastonite or transition zone. The actual amount of molybdenite present in the area is very great, but the proportion of this mineral to gangue is low.

History.—According to the statements of Messrs. W. L. Garrard and Z. Kirk, it would appear that, about twenty years ago, a prospector named Stephen Wade had been employed by a Mr. G. Blunt to search for valuable minerals in the locality under consideration, especially in the vicinity of the railway line from Tarana to Locksley. Wade brought specimens from the area now known as P.M.L. 9, near Mount Tennyson, and these were sent by Blunt to a firm of private assayers, who reported that the material was molybdenite, but of no commercial value. It must be remembered that molybdenite at this time commanded a very low price. Not long after this Wade, in his prospecting work, came upon a man named Hawkins, who was prospecting for copper in what is known now as Tonkin's Block, or P.M.L. 7. Hawkins

was prospecting a mass of garnet rock and he called Wade's attention to a mineral in the garnet which he did not recognise. Wade informed him that the mineral was molybdenite, but of no commercial value, and Hawkins thereupon left the claim. Thus closed one of the early chapters in the history of Mount Tennyson prospecting.

About Christmastime, 1913, it is stated that an article appeared in *The Sydney Morning Herald* dealing with the valuable mineral molybdenite. Mr. Z. Kirk read the article to Wade, who thereupon recalled to mind his experience of twenty years before in the rough rountry around Mount Tennyson. Next day the two commenced a search for the old prospecting hole, but found it only with difficulty, owing to the damage done by a bush fire in causing trees to fall over the spot. Having located the spot, sinking was continued to a depth of about 20 feet. Kirk applied for an Authority to Enter of 10 acres, and after further prospecting, both Kirk and Wade applied for an additional area of 20 acres, now P.M.L. 10. It was worked until June, 1914, when a Mr. Basset is reported to have inspected the area, and to have given his opinion to a newspaper concerning the deposit. A mild boom then resulted in " Yetholmes," and Kirk and Wade's blocks were surrounded on all sides by Authorities to Enter. During June and July, 1914, a general pegging of the area ensued from a mere inspection of the map, very little prospecting being done. In this way Mr. Buckridge is said to have secured P.M.L. 12 of about 40 acres. So keen was the rush for blocks that Messrs. Buckridge and Turner, and the Boyd Bros. are said to have applied at that time for an area of 76 acres surrounding Garrard's House.

Description of Main Properties.

A.—Mount Tennyson Deposits.

The many leases which comprise the Mount Tennyson area are included in the main within what is now called the Yetholme Options, Ltd., Kirk and Wade's, and Boyd's blocks. Besides these there are the Lithgow blocks, Field's and Garrard's blocks, Slade's blocks, and others. In the accompanying notes, however, the leases are described as they were seen during the visits by the Writer in November, 1915, and January, 1916.

1. Boyd's Blocks.—These include P.M.L. 12, about 40 acres, P.M.L. 11, about 5 acres, P.M.Ls. 23 and 33, each of 10 acres.

On H. Boyd's P.M.L. 11 of 5 acres, two open cuts had been made in January, 1916, at the head of a small but steep gully which cuts across the Lithgow block a little lower down the hillslope.

The main opening is about 10 feet in width, 50 feet in length, and about 25 feet in depth at the face. The whole thickness (27 feet) of the ore belt has been exposed in the face as the underlying sediments may be seen in the floor at one spot. A large heap of first-class ore was lying in the open cut, and stone of excellent quality was exposed in the face. The flakes were large and crowded, and a specimen of this ore may be seen in the Mining Museum at Miller's Point.

In October, 1916, a short visit was paid to Boyd's Blocks (P.M.Ls. 11 and 12). A considerable amount of prospecting work has been carried out since January. In P.M.L. 11, the open cut above mentioned is known now as Tunnel No. 1. A tunnel 100 feet in length has been driven along a vertical joint having a strike north 20° east. The average height of this tunnel is about 8 feet, but its width varies from 16 feet near the entrance to 27 feet

in the centre and 10 feet near the end. The thickness of the garnet rock was about 20 feet on the eastern side of the powerful joint mentioned, but on the western side the garnet rock containing molybdenite appears to continue to a depth considerably greater than on the eastern side. At the entrance of the tunnel a pit has been sunk to a depth of 18 feet below the general floor of the adit. The width of the pit varies from 6 to 8 feet and its length to 20 feet, the whole excavation being in garnet rock, the latter being 39 feet thick at this point. The work has been done under a quartz porphyry cap of slight thickness only, but the grade of the ore appears to be much richer than in the portions of the deposit which have had their caps or coverings of porphyry stripped from them by the weather. The amount of garnet rock removed in the excavation of No. 1 Tunnel appears to be 1,500 tons approximately on the assumption of 11 cubic feet to the ton, and the complete drillings from the holes bored for firing have been sampled, yielding an average for the tunnel, according to Messrs. Bethell and F. A. Cape, of 1·80 per cent. molybdenite. About 45 tons of rich ore, namely, 10 per cent., is said to have been bagged, and despatched from the tunnel. From an inspection of the heaps lying around the tunnel, I would consider the rejects to contain at least 1 per cent. molybdenite.

This work does not of necessity prove that the whole mass of the garnet rock under cover would average 1·80 per cent. molybdenite, but when it is remembered that the tunnel was chosen more or less at random and that the whole 1,500 tons has been proved apparently to contain this percentage, it must be considered that this latest prospecting work is highly encouraging.

A series of bores has been put down in P.M.Ls. 11 and 12, in the porphyry and these have proved the existence of immense bodies of similar garnet rock. These reserves had already been shown on the accompanying map, prepared in November, 1915, and based on the work both of Mr. Carne and myself in July and November, 1915.

2. Buckridge's Block, or P.M.L. 12.—Nos. 4 (Pl. XXV *a*), 5, 6, and 10 open cuts have been made on this lease, which contains many acres of garnet-molybdenite outcrop, here forming the cap to a wide spur point (Pl. XXV *b*), and from which the track leads gently to the main plateau beyond (Pl. XXVI *b*).

These cuts are arranged, for the greater part, around the denuded margin of the great garnet outcrop. A couple of smaller cuts, however, have been made in the central portion of the outcrop. The accompanying sketch map illustrates the positions of the larger of the cuts. The more important of these open cuts or holes appears to be the western, or No. 4, which overlooks the Lithgow block. It (Pl. XXV *a*) has a greatest length of about 50 feet, a greatest width of about 25 feet and a greatest depth of about 17 feet. These dimensions are excessive for purposes of computation of volume, inasmuch as the continuity of the cut is broken in places by large masses of rock in place. A large heap of ore averaging, approximately, 3 or 4 per cent. molybdenite, was seen at the entrance to the cut. From an examination of the waste and the selected material, it seemed probable that 10 tons of ore had been picked to produce 1 ton of grade from 3 to 4 per cent. molybdenite. I am informed, however, by Messrs. Boyd and Marshall, that a considerable tonnage of ore, exceeding 5 per cent. molybdenite, had already been despatched from the cut, and this would, of course, necessitate the raising, in some measure, of the average grade of the ore seen in the heaps.

[*Photo J. H. Faweett.*]

(*a*) No. 4, Oper Cut. Boyd's or Buckridge's Block, P.M.L. 12.

[*Photo J. H. Faweett.*]

(*b*) General view Buckridge's Block, from Experimental Plant. Hill in middle distance forms garnet outcrop.

Several of the other cuts are fairly large, and contain rich specimens. This applies more particularly to the cut originally known as No. 8. The majority of the openings, however, appeared to contain ore much poorer in quality than No. 4.

With regard to the future of this large ore deposit, namely, that contained in P.M.Ls. 11 and 12, it is obvious, from what has been written above, that the average tenor of the mass, in molybdenite values, is somewhat low. On the other hand, the ore is so patchy in nature, and the size and position of the richer patches are quite unknown, that the proper method of working the deposit is by quarrying it as a whole, and picking before transport to a mill designed for oil flotation on a wholesale scale.

Since the report was written, information has been received from Mr. Bethell, of 4, Bridge-street, in connection with the development of the property. Eight bores in all have been put down in various positions on the leases. An immense body of garnet-rock containing molybdenite has been proved to exist by this means within P.M.Ls. 11, 12, 23 and 33, probably from 3,500,000 to 4,000,000 tons. Incidentally the supposed nature and extent of the garnet rock as represented on the accompanying sketch geological map has been borne out by the boring. A maximum thickness of 34 feet is reported from the southern exposure of the garnet rock in P.M.L. 12, whereas from a field examination of the outcrops the maximum thickness had been placed at 30 feet approximately by Mr. Carne and the Writer. Tunnels and open cuts also have been put in the garnet rock in P.M.L. 12. These in turn have helped to demonstrate the sheet-like nature of the deposit. It may be pointed out also that a study of the map suggests the occurrence of garnet belts subparallel with the main one in Kirk and Wade's block, although the opinion of the Writer is that the garnet rock in the Lithgow and Boyd's blocks is continuous and hidden under a cover of altered quartz-porphyry, varying in thickness.

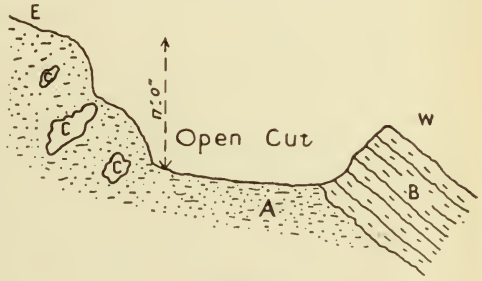


Fig. 40.

Sketch section across No. 4, Open Cut, Parish of Yetholme.

A—Brown granular garnet rock, containing silicified blocks of sediments, small patches and blebs of quartz, with flakes and patches of molybdenite.

B—Altered sediments.

C—Silicified sediments, or porphyry.

3. Kirk and Wade's.—The area held by this Company is about 50 acres, and the original prospecting area is P.M.L. 9.

The geological occurrence of the molybdenite deposits within Kirk and Wade's blocks is somewhat different from that of the areas already enumerated. Thus the greater portion of the deposit within Boyd's P.M.L. 12 occurs as a superficial and tabular deposit from 5 to 25 feet in thickness, forming a cap to a broad and blunt spurpoint, whereas, in Kirk and Wade's, the deposit dips into the steep hillside at a moderate angle.

The main workings occur as open cuts, totalling about 60 or 70 yards in length, and situated within both P.M.Ls. 9 and 10, near their common boundary.

The gangue is garnet, with inclusions of what appears to be either silicified claystone or volcanic ash, and the greatest depths of the garnet mass, as proved in the open cuts, is about 25 feet.

Heaps of picked ore, lying in the open cuts, amounted possibly to as much as 15 tons, and ore of poorer grade amounted, possibly, to 75 tons. The picked ore appeared to contain 3 per cent. molybdenite, and the poorer class of ore appeared to contain from 1 to $1\frac{1}{4}$ per cent. molybdenite.

It must be remembered that these estimates, as also those given elsewhere in this report for the Yetholme field, are not based upon the results of sampling and assaying, but are merely a personal opinion based upon an inspection of the various open cuts.

As the workings are continued beneath the sedimentary cover, it is very probable that the molybdenite content will be found to be much greater. Mining would be more expensive here than in P.M.Ls. 11, 12, 33, 5, 18, 15, and 19.

4. Kirk's (Z.) Block, or Lithgow (The) Company.—This Company holds P.M.L. 15 of 42 acres and P.M.L. 19 of about $9\frac{1}{4}$ acres.

The whole of the area is in very rough and steep country, being drained by two deep ravines.

The main workings occur as open cuts in the base of a steep gully below the large outcrop in P.M.L. 12, or Buckridge's claim. They are indicated on the geological map of Yetholme, within P.M.L. 15.

In this lease the main garnet mass outcrops as a closed curve on the steep hillsides, dipping under them in all directions (*see* section across Yetholme Field). Formerly the mass stretched clear across the gully or ravine, but it has been worn away by stream action in recent geological time.

Two open cuts have been made in the tabular molybdenite deposit, the larger one being about 100 feet in length, with a greatest depth of about 20 feet, with an average width of about 10 feet. These cuts have been excavated in garnet rock, but the underlying claystones or volcanic ash-beds, have been exposed near the creek in the lower workings. From these openings it is stated that about 20 tons of ore, averaging from 3 to 5 per cent. of molybdenite have been won, as also 50 to 60 tons, averaging about $\frac{1}{2}$ per cent. molybdenite.

A study of the accompanying sketch map indicates that the Lithgow leases contain huge deposits of garnet rock with molybdenite underlying a moderate thickness of quartz-porphyry. It is highly probable that the quality of the ore under the cover is much better than that exposed in the original open cuts. In my opinion the great masses of garnet rock occurring in the western portion of P.M.L. 15 will not be so rich as those in the eastern, north-eastern, and south-eastern portions, inasmuch as the lime and wollastonite content is too great in the western portion of the lease.

This area is one of great promise, provided a cheap method of concentration be devised.

5. Field and Garrard's Blocks.—These include P.M.Ls. 18 and 5, totalling 20 acres. The blocks together form a square, as is shown on the Yetholme map, and they lie on a very steep and rugged gorge overlooking the Western Railway Line.

The great tabular molybdenite deposit outcrops strongly in these leases, and several open cuts have been made within it by Mr. Garrard, exposing molybdenite ore of a grade somewhat similar to that found in Buckridge's (P.M.L. 12), Kirk and Wade's (P.M.Ls. 9 and 10), and the Lithgow (P.M.L. 15),

PLATE XXVI.

[*Photo J. H. Fawcett.*]

(*a*) Kirk and Wade's Mine. Open Cut, in garnet rock.

[*Photo J. H. Fawcett.*]

(*b*) Garrard's House and Mount Tennyson (near summit).

blocks. In this, as also in other blocks, it was noted that large masses of altered country showed rich films of molybdenite, in places, round their margins. The garnet mass is also divided by strong master joints and angles along certain of which the molybdenite content is relatively great.

An examination of the sketch map prepared in 1915 indicates that there is an immense tonnage of garnet rock containing molybdenite in these leases, all covered by quartz-porphyry of moderate thickness only, say not exceeding 100 feet, except at a very few points, where it may be 120 feet thick. The present prospecting is being done on the outcrops. It would be advisable to test the deposit under the porphyry, and as far east as practicable, inasmuch as the western portion of the leases contains too much carbonate and silicate of lime. The prospecting is of a very hopeful nature.

6. The Yetholme Molybdenite Options, Ltd.—These include Field's block P.M.L. of 2 acres; Kirk and Wade's No. 1 South, 8¼ acres Howe's block P.M.L. 13, 15 acres; Gorman's blocks, 15¼ acres, including P.M.L. 14, 8 acres approximately; Boyd's No. 1 South, 10 acres; Boyd's No. 1 East, 20 acres; Wade's No. 1 West, 30 acres; Wade's North, or P.M.L. 7 of 5 acres; Wade's North-East, 2½ acres; Tonkins' West, 4½ acres; Tonkins' East, 15 acres; Tonkins' block, being P.M.L. 3, nearly 10 acres; Holland's block, or P.M.L. 4 of 20 acres.; T. Boyd's blocks, being P.M.Ls. 8 and 17, of 5 and 15 acres respectively; Berry's block, being P.M.L. 11 of 5 acres approximately, and P. Slade's block, 20 acres, as also certain dam sites.

These may be seen on the accompanying map of Mount Tennyson. Most of the areas have been prospected, and the garnet lode with molybdenite occurs within the majority of the areas. The class of molybdenite ore worked is similar to that in Kirk and Wade's, Buckridge's, The Lithgow, and Field and Garrard's blocks.

7. Other Blocks.—These include Slade's block, or P.M.L. 22, of 8¼ acres, and P.M.L. 21, of 20 acres, surrounding Garrard's House and adjoining P.M.L. 17 on the West. These have not been prospected to any great extent, but the garnet lode should be strong under the porphyry cover in P.M.L. 22. Its quality is not known, however, as the lime content is not known.

(*b*) Gemalla Deposits.

These lie a couple of miles easterly of the Mount Tennyson deposits in very rugged country. It is highly probable that the Mount Tennyson and the Gemalla deposits have been connected across the deep gorges at some former period. It is also highly probable that certain portions of the deposits may lie beneath the bases of the great ravines which roughen the country so much between Mounts Tennyson and Tarana. It may be also that prospecting operations will reveal outliers of the once-coextensive garnet deposit between Gemalla and Mount Tennyson.

At Gemalla, as at Mount Tennyson, the garnet has been worn away in great measure by stream action; but immense residuals occur on the high and steep spurs which radiate from the Mount Tarana mass. The Macquarie or Fish River, near Gemalla, is about 2,450 feet, while the highest points around the molybdenite occurrences exceed 4,000 feet, above sea-level.

The molybdenite outcrop first seen by the Writer was in the bed of a creek, tributary to Eusdale Creek, about half a mile up this tributary creek above its point of discharge into Eusdale Creek, and in the south-easterly portion of Portion 125 of 1,270 acres, a homestead selection, taken up by Mabel Reakes, Parish Eusdale, County Roxburgh. This exposure in the side creek

is known as Reakes' Claim. It is about 200 feet above the main creek bed at Reakes' house. The strike of the deposit at the claim lies a little west of north, and the dip is about 26 degrees in a direction from 70 degrees to 80 degrees east of north. The deposit is a red garnet rock of fine texture, containing also green garnet, a green ferromagnesian silicate, epidote, calcite, iron pyrites, a little zinc-blende, and white and transparent quartz patches, blebs, and eyes. The footwall appears to be a dense porphyry, and the hanging wall appears to be a banded and altered sediment of calcareous nature. The total thickness of altered rock appeared to be from 40 to 50 feet stratigraphically, and the thickness of the garnet-molybdenite tabular mass was from 20 to 25 feet. In some places in the vicinity the thickness, however, was less than this.

The workings in Reakes' Claim consisted, as seen in November, 1915, of a tunnel 30 feet long in the right bank of the creek, and a hole about 20 feet long, 10 feet wide, and 8 feet deep, in the bed of the creek on the left bank side.

In this claim the molybdenite content was not rich.

Thence to the north the outcrop could be traced for a considerable distance leading up to the north-west corner of the Surface Right, within Slade's P.M.L. 6, of 20 acres. The south-west corner of this surface right is about 400 feet above Reakes' Claim in the creek, and the north-west corner of the surface right is about 600 or 650 feet above this same datum. Slade's Authority to Enter lies immediately to the east and north of P.M.L. 6, and extends along a high spur for hundreds of feet vertically above P.M.L. 6. The particular garnet deposit examined in Reakes' Claim of 40 acres appears to strike through Slade's Authority to Enter, as sighted along various points of the outcrop lying to the south; nevertheless it was seen neither by the Writer nor by Mr. Reakes in a joint excursion through the rough country. This particular deposit does not appear to outcrop on P.M.L. 6, unless the dip should have changed within a short distance to the east from Reakes' Claim.

Leaving Reakes' workings to the north, and ascending the hillside on the right-hand side of the creek, the deposit may be seen to outcrop on a ridge about 700 feet in a southerly direction. Here the garnet-molybdenite deposit makes a bold outcrop and forms the slope of the hill for some distance eastwards towards the creek at Reakes' workings. The angle of slope is about 26 degrees. Thence throughout Reakes' 40-acre block, across Jacques' block (Portion 95), to the south it was traced as a very well-marked deposit, the dip flattening slightly to the south. Especially strongly did it outcrop on both sides of a steep gully leading into Eusdale Creek. As measured in the creek bed, the deposit was of considerable thickness, possibly 20 to 25 feet, and it appeared to have a footwall of rock somewhat resembling diorite. The outcrops here were continuous and wide and of a reddish colour, suggestive of a gossan lode.

Thence to the south it was traced into Tonkins' block, of 20 acres, and almost to the north-west corner of portion 47, near which point it disappeared into the siliceous granite of Gemalla.

Future of Yetholme Field.—There is no question of the existence of vast quantities of molybdenite ore within the Yetholme and associated areas. The question is: Is the molybdenite content of the ore sufficient to return the expense of mining treatment and realisation? Eighteen months ago most mining engineers thought the field was valueless. At that time the

PLATE XXIII.

[*Photo E F. Pittman.*]

The Whipstick Mines.

leached outcrops only had been prospected, and these were known to possess only a very low content of molybdenite. It mattered little that an amount of ore exceeding 20,000,000 tons occurred within a square mile, and near the surface at that, provided that the percentage of molybdenite contained therein was insufficient to justify the treatment of this tonnage. But quite recently one party at least has prospected the ore underlying the porphyry and sedimentary cap, with the result that the work done, although very limited, is highly encouraging. It is, of course, only to be expected that a mineral such as molybdenite would be protected by a capping of dense rocks, whereas it is more or less attacked by weathering near the surface. In any case the tunnel driven in P.M.L. 11 indicates a content of molybdenite over a limited area exceeding 1·50 per cent., while specimens seen by the Writer and purporting to come from the prospecting within the Lithgow Block (P.M.L. 15), also suggest the advisability of continuing the prospecting operations there on a much larger scale. In the opinion of the Writer a vigorous prospecting campaign is to be commended on blocks such as P.M.Ls. 11, 18, 15, 5, 9, 10, 23, 22, 33, 12, and east of 33. This prospecting might consist of the driving of several tunnels at different points on each block, and the sinking of shallow shafts through the cap of porphyry or sediments. Such tunnels and shafts could be selected after consultation with the Government Geologist and the Writer so as to avoid the limestone beds (Pl. XXVII) as much as possible, and to secure sinking as shallow as possible consonant with the securing of the best results.

In my opinion the deposits should be worked in a very large way, since the ore tonnage is immense and the molybdenite content is too low to permit of working profitably on a small scale. The gangue is a clean silicate almost free from impurities, so called. Experimentation by a skilled student or engineer in all probability would result in the concentration of the fine-molybdenite content as cheaply as the concentration of copper slimes, say, for 8s. a ton, including picking before concentration.

Mining and development of a seam of low pitch such as this in the steep Yetholme country should not exceed 10s. a crude ton, as may be seen by a comparison with the costs of deep mining as at Broken Hill, Cobar, Mt. Lyell, and other places. If 300,000 tons be treated a year, the mine should be equipped for £125,000 to £150,000, exclusive of railways or aerial tramways. The molybdenite may be considered to be concentrated to 80 per cent. grade, for a 90 per cent. recovery after being picked, in the first place, over belts to a 4 per cent. grade for an 80 per cent. recovery. Thus 72 per cent. of the ore may be considered as saved. The life of the larger leases on this yearly tonnage may be taken at five or six years. Then neglecting the cost of bags, and bagging of, and railway freight on, the concentrate (80 per cent. grade), the expenses per crude ton may be estimated as follows :—

	£	s.	d.
Mining and development	0	10	0
Picking and concentration	0	8	0
Redemption of Capital at 10 per cent. interest for plant and equipment	0	3	6
Redemption of capital as purchase money (say)	0	2	6
Or a total of	£1	4	0

Taking the margin of safety at 25 per cent. or 6s. a crude ton, the total expenses may be considered as £1 10s. a ton.*

If the whole mass of the stone should thus equal ·50 per cent. and upwards of molybdenite, these properties should be able to make good profits. The cost of bags, bagging, and realisation per crude ton to Sydney would be but slight.

It may be objected that the production of large quantities of molybdenite would cause a fall in price. This may be so, but, on the other hand, it is highly probable that the present small supply of the world's molybdenite explains why it is not in more general use among steel manufacturers.

(*c*) The Tarana Deposits.

1. Borchardt and Roos' Claim.—This claim is an isolated one on the eastern slopes of Mount Tarana, a bold and rugged mountain, rising about 1,750 feet above the river at Tarana. The claim worked in 1915 was included within M.L. 1 of 80 acres, Parish Fusdale, County Roxburgh, and was approached within half-a-mile by the Diamond Swamp road, leading from Tarana to the main Sydney road. The claim itself lies 200 to 800 feet above the Diamond Swamp Creek, and is in very rough country. The molybdenite deposit occurs in siliceous granite at its intrusive contact with sediments of early Palæozoic age, 500 feet above Diamond Swamp Creek, and the granite itself is a local swelling, as it were, on the main Bathurst granite mass, which has intruded the sediments for a distance of a mile around in such a manner that the bedding planes of the sediments have the same dip as the intrusive contact-surface of the granite. From the main granite mass at Tarana this local outcrop apparently is separated by a wide belt of sediments, which descend below the river level, nevertheless the granite exposure under consideration is connected below the sediments with the Bathurst mass.

The granite at its margin assumes a pegmatitic and aplitic appearance in places. In such types, especially at the spots where the aplite or pegmatite is filled with small holes of irregular shape, the molybdenite occurs in small flakes. These molybdenite deposits occur on the sides of a very steep gully, near its base. On the left bank a mass of pegmatitic quartz outcrops about 14 feet in length and 10 feet in width. This may be the outcrop of a pipe, or it may be only a large bunch of quartz with a little felspar content. More prospecting would need to be done to settle this point. The molybdenite occurs in flakes scattered irregularly throughout the quartz. Somewhat less than half a ton of ore has been won from this quartz, but the molybdenite content is low apparently, not being more than half of 1 per cent.

A few yards down the hillside from the quartz, and at the granite contact, a long and shallow open cut has been made in the pegmatitic granite. Throughout this material molybdenite flakes of small size are scattered as accessory constituents. The molybdenite content is very low, as in nearly all such aplitic or pegmatitic segregations, as at Moonbi, Laura Creek, Wilson's Downfall, Tenterfield, and Tantawanglo. From this pegmatitic granite a small heap of low-grade ore has been won.

Another open cut has been made at the granite contact on the opposite bank of the creek, about 100 yards due south from the quartz outcrop, and 90 feet lower vertically. This cut is about 20 feet in length, about 17 feet in depth at the back, and is in the form of two benches from 8 to 10 feet wide.

* All this, however, implies the discovery of a cheap and effective method of concentration.

This opening has been made in a fine-grained mixture of felspar and quartz. A heap of about 3 tons of very low-grade ore, both spalled and unspalled, lies in the cut.

The molybdenite in these open cuts in the granite proper is not concentrated enough naturally to repay mining and treatment expenses. Tho quartz outcrop has not been prospected sufficiently to justify any opinion ef value as to its possibilities at greater depth.

About $3\frac{1}{4}$ chains up the left-hand branch of the gully, a tunnel has been driven to the north in the left-hand creek-bank. The length of the tunnel is about 15 feet. It has been driven in sediments, exposing a network of veins of iron pyrites, zinc-blende, and other minerals in quartz.

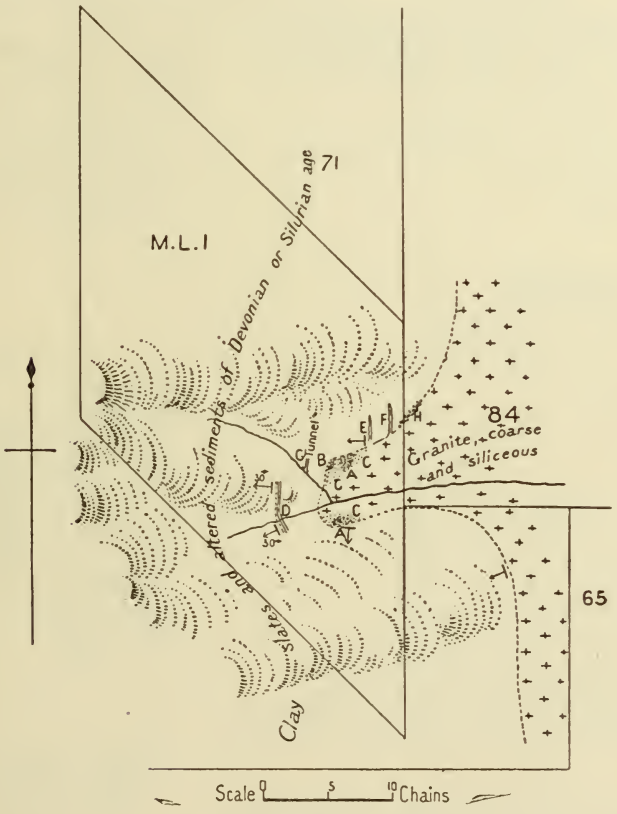


Fig. 41.

Sketch map of Borchardt's Lease, M.L. 1, Parish of Eusdale, County of Roxburgh. The sediments overlie the granite, and the dip of the granite surface around the lease coincides with the dip of the sediments.

A—Large pegmatite outcrop with molybdenite.
B—Quartz outcrop with molybdenite.
C—Fine-grained pegmatite.
D—Granite sill with associated sediments altered to garnet, wollastonite, epidote, limestone, chert, and amphibolite.
E—Band of sediments (claystones?) altered to chert, epidote, &c.
F—Granite sill.
G—Tunnel on lode, containing zinc-blende, copper, and iron.
H—Granite here filled with large fragments of claystone.

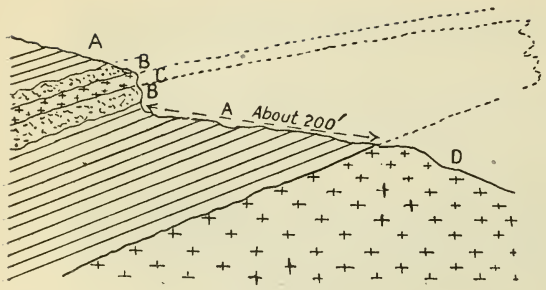


Fig. 42.

Sketch section of granite intrusion at Borchardt and Roos' Claim, M.L. 1, Parish of Eusdale, County of Roxburgh. Based upon measurements by Dr. H. E. Gregory and E. C. Andrews.

A—Fine-grained silicified sediments.

B—Sediments altered to wollastonite, garnet, &c.

C—Fine-grained granite sill.

D—Siliceous granite.

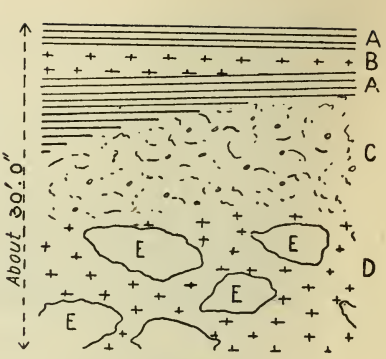


Fig. 43.

Sketch of marginal phase of granite intrusion, M.L. 1, Parish of Eusdale.

A—Fine-grained sediments.
B—Small granite sill.
C—Talus on hillside.
D—Coarse siliceous granite.
E—Angular masses of sediments.

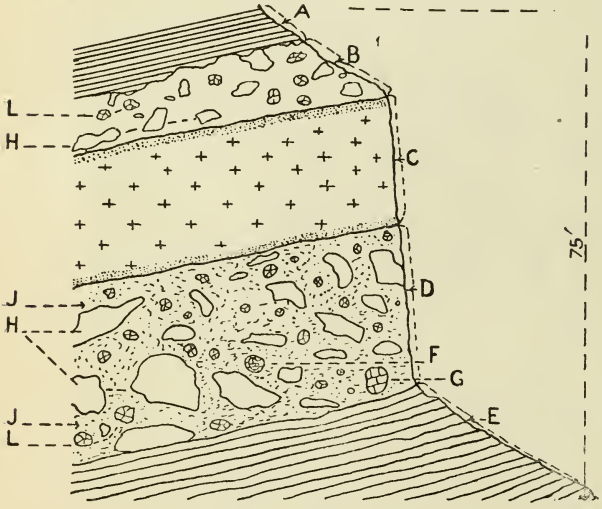


Fig. 44.

Sketch of cliff section in Borchardt and Roos' Claim, M.L. 1, Parish of Eusdale, County of Roxburgh. Based upon measurements taken by Dr. H. E. Gregory and E. C. Andrews.

A—Fine-grained silicified sediments.
B—Sediments altered to garnet, wollastonite, &c.
C—Fine-grained granite sill with felsite-like margins.
D—Fine-grained sediments altered to wollastonite, garnet, epidote, &c.
E—Fine-grained and laminated sediments altered to quartzites.
F—Marble inclusion with external zone of wollastonite.
G—Marble inclusion. (See Fig. 37, No. 2.)
H—Fragments of silicified sediments.

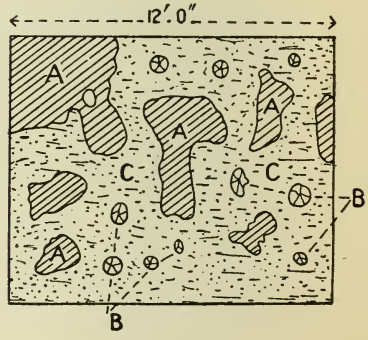


Fig. 45.

Sketch of detail of Devonian or Silurian sediments altered by quartz-porphyry sill, P.M.L., Parish of Eusdale, County of Roxburgh.

A—Large silicified fragments of sediments.

B—Aggregates of spheroids of wollastonite.

C—Paste of garnet, wollastonite, and allied minerals.

Along the right-hand branch of this creek, and about 80 yards above the granite claystone contact, the interesting outcrop already noted occurs, where a sill of fine-grained granite intrudes sediments of fine texture, and has altered the sediments in the form of deep irregular networks (Fig. 45), or pockets both below and above the sill. This alteration has taken the form of converting claystone, ash, or sandstone, beds, to quartzite, while within these quartzite beds, networks, spheroids, ellipsoids and irregular masses of marble, wollastonite, granular garnet, amphibole (?), epidote and chert have been developed abundantly.

Yetholme Options, Ltd. *See* Yetholme.

Young and Reid's Claim. *See* Whipstick.

Zeph. Kirk's Blocks. *See* Gemalla, Oberon, and Yetholme.

XII.—THE OUTLOOK FOR THE MOLYBDENITE INDUSTRY IN NEW SOUTH WALES.

Only 31¾ tons of molybdenite were exported during 1915, in spite of all the money spent on prospecting, mining, and erection of plants in the State. This, upon first consideration, would appear to be due to an indifference on the part of mine-owners to the question of production, but it is really due, in very great measure, to an inability, up till the present time, to produce a cheap and effective method of recovering the molybdenite from the gangue, or the associated ores, such as bismuth or wolfram. Owners and lessees of ground containing pipes are unwilling to expend much money and labour in winning ore which again is to be taxed by enormous charges for treatment. On the other hand, they cannot afford to erect suitable plants for themselves, inasmuch as they have little or no ore in sight in their pipes, and, moreover, the cost of running the plant, even if erected, would be enormous. They therefore prefer to work their deposits leisurely, hoping for some cheap and efficient method of treatment to be devised. Thus the owners of the Rocky River pipes should be producers of a much larger quantity of ore than they are at present, but they have been unable, in certain cases, to solve the complex problem of the treatment of their ores up to the present. They are handicapped also by the heavy cost of freight to rail. The Kingsgate, Deepwater, and Bolivia, pipes are not working at anything approaching high pressure. Whipstick, however, has its own mineral separation plant now, and should be an important producer during 1916 and onwards.

The Yetholme, Booroolong, and Black Range deposits are large, but the owners still have not devised a simple and effective method of treatment. If these could only be picked cheaply prior to flotation to a grade of 4 or 5 per cent. molybdenite, and then treated for 8s. or 10s. a ton on this ore so picked, then it might be possible for these areas to become very important producers. Especially does this apply to the case of Yetholme, whose ore reserves are immense, the mining of which would be very cheap, and the prospects of which appear to be exceedingly encouraging.

Up to the present we have had to depend upon our " pipes " for molybdenite supplies, but in the near future we may look to true reefs, as at Bega, or to great seams, as at Yetholme, for supplies. In the Writer's opinion, it should be possible for New South Wales to produce hundreds of tons a year of high-grade molybdenite concentrate from the pipes, seams, and veins, above-mentioned. Moreover, other pipes may be expected to be found by a systematic prospecting of the marginal areas of the Deepwater and Bolivia and other molybdenite granites.

It must be remembered that any cheap method of treating molybdenite ores effectively would be employed in Canada, Norway, and other countries possessing low-grade molybdenite ores, thus causing a sudden and large increase in the world's supplies. It is possible, however, that this condition of things would not produce a glut, as it is probable that the knowledge of a definite supply of this material would encourage its more extended use.

On the whole, the outlook for the industry is very encouraging, as a lessening in the cost of production, even if slight, in all probability would lead to a much greater output from the pipes. It is useless to discuss the ore reserves

of the pipes of New South Wales in tons, as the ore is removed in great measure during development and prospecting operations. It is a legitimate inference, however, that the pipes worked up till now may be expected to persist to depths much greater than those worked at present. It is almost certain also that the deposits of New South Wales could yield large quantities of 80 per cent. grade molybdenite concentrate a year for several years to come if such a production were urgently demanded. Yetholme, perhaps, is the field from which the great supplies may be expected in the future, when cheapness of treatment has been effected.

APPENDIX.

Allies Mine, 6 Miles East of Deepwater.

(*See* pp. 75, 76 of Main Report.)

The following rough measurements may furnish an idea of the general appearance of this important deposit in September and early October, 1916 :—

From the eastern edge of the outcrop the deposit was traced in a southerly direction for a distance of 40 feet approximately. Along this portion of the pipe the breadth and height were about 5 feet. The width, however, exceeds the height in the majority of the transverse sections throughout the deposit.

Thence the main pipe was traced a little south of west for 63 feet, near which point of bending to the right the deposit was worked by a vertical shaft 35 feet deep, 18 feet of which was sunk through the slate cover. The deposit was worked thence in a more southerly direction for a distance of 50 feet, near which point a vertical shaft 55 feet in depth was sunk to facilitate mining operations. This shaft is said by Mr. J. Watson, manager of the mine, to have been sunk 15 feet through the slate cover before reaching the granite. Near this point the deposit was found to be larger, steeper, and very much richer in molybdenite. The discontinuous core of quartz which had been noted in the upper portions of this granite pipe was replaced by a long vugh of tortuous shape, and an average height of 2 feet and a width of 3 feet. A chamber had been excavated within this portion of the deposit, and the main direction here appeared to be a little south of west for a distance of 23 feet, the farthest point reached on September, 1916. Beyond this the vugh could be seen for a distance of 8 feet, and a direction south-south-west. The greatest widths of the chamber as measured were 10 and 12 feet, and the average height appeared to be 5 feet 6 inches.

The appearance of the face is strikingly like that exposed in the best portions of the great chamber in the Old 45, or Sachs' Pipe. The chamber in the Allies Mine is not as large as that worked in Sachs' deposit, nevertheless it is impossible to forecast what dimensions it may be found to possess at a lower point.

The vugh or cavern is lined with quartz and molybdenite crystals. The quartz crystals may be double-headed, but they consist, in the main, of forms attached solidly to the walls with facets and pyramid faces projecting into the vugh. The molybdenite occurs as large and deep crystals formed of thick plates, generally six-sided, and arranged in a manner such that the lower plates are broader than the upper ones, while the crystal plates, as observed, appeared to be contorted and concave from the base upwards. The basal cleavage is revealed in a striking manner by the crystals (Pl. XXVIII). The largest crystal observed was about 8 inches wide and 4 or 5 inches deep. The average width and depth of the crystals lining the great vugh appeared to be about 4 inches and the depth 3 or 4 inches, the basal planes apparently being arranged at right angles to the longer axis of the vugh or pipe. For a distance of 15 to 20 inches from the margin of the vugh the material of the pipe appeared to be composed of more than 50 per cent. of molybdenite by weight. No native bismuth nor sulphide of bismuth was seen in the ore surrounding the vugh, but large pieces of such ore occur in the deposit, the native metal occupying interstitial spaces between quartz crystals in the main. Beyond the wide zone surrounding the vugh the molybdenite was

PLATE XXVIII.

Molybdenite with quartz, from Allies Mine, Deepwater.

much less, but very rich nevertheless. It is impossible to give any reliable information as to the length and width of this rich deposit beyond the present face, but the indications are very favourable for the expectation of a considerable to large tonnage of this rich ore.

The success which has attended the efforts of Mr. Baker and his manager, Mr. J. Watson, is well-deserved, inasmuch as many prospectors would have abandoned the work long ago owing to the excessively heavy cost of mining, and the poor nature of the ore in the upper portions of the deposit. Mr. Watson has kept on the pipe, and Mr. Baker has persevered in the search with the greatest confidence in the ultimate success of the venture.

This success of Mr. Baker's work affords an additional opportunity for the Writer to draw attention to the decided advisability of prospecting afresh the Bow Creek pipes, which are very promising in general appearance. The whole of the Bow Creek granite margin should be prospected for other pipes, also the Booroo (Splitter's Creek), the Wunglebung, the Kingsgate, and the Whipstick, granites. There is no reason to doubt the existence of pipes, similar to those already known, near the intrusive margins of these granites, but which do not outcrop owing to an overburden of earth or rubble.

Holbrook.

The accompanying notes have been supplied by Mr. H. Hooke, Mining Inspector :—

Beginning just north of the Jingellic Road abreast of the Annandale Homestead, about 4 miles south-east of Holbrook, a high ridge occurs amongst a number of others. Along this particular ridge and across intervening gaps in same a number of quartz veins can be traced in a northerly and southerly direction for a length of fully 6 miles. Most of these veins contain molybdenite.

The veins vary in width from 8 inches to 4 feet; they have the same general trend, namely, south-west, and underlie usually to the south-east, or stand vertical.

The quartz is firmly adherent to the walls, the veins not being set in channels in the rock. Some of them are in more or less vertical joints in the granite, which has a banded structure. The granite is hard and unaltered right to the surface, and there is but little oxidation of the mineral in the veins, which latter, however, show a large number of cells which apparently had contained molybdenite. The granite is of the sandy nature usually favourable to molybdenite deposits.

Near the Jingellic Road and within sight of it, the Holbrook Prospecting Syndicate (Wm. Hicks, Secretary) has opened three veins on G. Walker's 40-acre lease. The first vein one reaches on ascending the hill is about 8 inches wide and traceable for several chains. Along this vein open cuts have been made to depths of a few feet. Molybdenite is present wherever the quartz is broken. Most of this is coarse, there being but little finely divided mineral visible.

The middle vein of the three is still higher up the hill and to the north-west. It is about 4 feet wide and also some chains in length. It does not appear to be so rich as No. 1 vein, but being in somewhat softer country its prospects are no worse. In this vein pieces of molybdenite 3 inches across are not unusual.

† 68791—G

No. 3 vein is nearer the summit of the hill and to the west. An open cut has not disclosed much of the mineral sought, but at the top of the hill this vein, which is about 3 feet wide, has been opened by a shaft 25 feet deep. This exposes a series of makes of quartz junctioning and crossing, making a pipe which has yielded molybdenite freely.

Beyond the " Holbrook " lease, about 3 miles, some work was done upon a quartz vein by Mr. Waxsmith a few years ago. Here a shaft was sunk to 30 feet, but work was discontinued on the outbreak of war, the holder of the block being an alien.

About 1 mile still further north of the above, on Bruce's Hill, Riedel and Cantrell (of Holbrook) have opened two shallow shafts from which some coarse molybdenite was obtained, say half cwt. Here there is very little quartz showing, but a well-marked fracture in the rock is apparent along which and connecting with it veinlets of quartz and molybdenite have been opened.

This is practically all that has been done upon these veins. No ore in bulk has been sent away for treatment, but some molybdenite has been obtained by hand-picking.

On all these sites the conditions of veins and rock are similar. Doubtless in between the places mentioned other discoveries will be made.

Stream tin is fairly abundant in the creeks and banks at foot of hill. Wolfram and scheelite occur in the locality and bismuth is present.

Deepwater.

Rossington and McCusker's Claim.—Held under Authority to Enter. Parish Parkes, County Gough. About 11 miles north-east of Deepwater.

According to Mr. George Smith, Inspector of Mines (P.B. Papers, 16/3813 Mines), the deposit under consideration is an impregnation in granite near its intrusive junction with claystone or slate. The minerals sought were molybdenite and wolfram. Two shafts had been sunk on the deposit 17 and 30 feet respectively in depth. Aid was sought and granted to sink the deeper shaft to a depth of 50 feet.

Yetholme.—Boyd's, Kirk and Wade's, and the Molybdenite Option companies are now stated by Mr. G. M. Bethell to be included in The Mammoth Molybdenite Mines.

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